YIELD AND QUALITY OF TRICKLE-IRRIGATED TOMATOES AS AFFECTED BY N AND K APPLICATION

BY

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Tomatoes (Lycopersicon esculentum Mill.) were grown during 2 seasons to evaluate the effect of trickle-applied N and/or K, percentage of trickle-applied nutrients (50-100%), and schedules of nutrient application (variable, 2-12.5% weekly and constant, 8.3% weekly) on fruit and shoot yield, external and internal blotchy ripening, and leaf, shoot, and soil mineral nutrient concentration. Crops were grown on mulched beds of an Arredondo fine sand (2% organic matter, 28 ppm Melich II extractable K, volumetric water content at field capacity 0.11 $mm^3 \cdot mm^{-3}$). The daily irrigation requirement, calculated at 47% of the water evaporated from a U.S. Weather Service Class A pan, was met by the application of 0.46-0.72 cm $water \cdot day^{-1}$. Fertilizer was injected weekly during the first 12 weeks of each season.

Higher yield of marketable fruit at the early harvest period was obtained with trickle-applied K (preplant-applied

N) than with trickle-applied N and K together (N+K) and trickle-applied N. Linear decreases in yield at the early and total harvest periods were obtained as the trickle-applied percentage of nutrients increased from 50 to 100%. Trickle-applied nutrients and trickle-applied percentage of nutrients interacted in their effects on fruit yield at the early, midseason, and late harvest periods. When N+K and N were trickle-applied, the mean yield of marketable fruit at the early harvest decreased linearly from 25.3 to 16.3 $t \cdot ha^{-1}$ as the trickle-applied percentage of nutrients increased but when K was trickle-applied a significant change in yield was not obtained (mean 26.3 $t \cdot ha^{-1}$). Similar trends were obtained for the total yield of large fruit. The weekly schedule of nutrient injection had few significant effects on fruit yield or other parameters.

External and internal blotchy ripening was less severe (higher fruit quality) when N+K were trickle-applied than when N and K were trickle-applied individually. Internal fruit quality improved as the trickle-applied percentage of nutrients increased but significant differences in exterior quality were not obtained. Internal fruit quality was higher early in the season than late in the season during both years. A consistent trend in external fruit quality within harvest periods was not obtained. The highest yield of high quality fruit was obtained with 50% trickle-applied N+K. High fruit N, P, Ca, Mg, and especially K concentrations were also obtained with trickle-applied N+K.

Late in the season, high leaf N and K concentrations were obtained with trickle-applied N+K. When N and K were trickle-applied individually, high concentrations of the respective nutrient were obtained. Treatment effects on shoot mineral nutrient concentration were not consistent.

CHAPTER I
INTRODUCTION

Florida supplies a large portion of the fresh vegetables consumed in the United States and Canada throughout the year except in the summer when it is too hot, humid, and rainy for the production of many crops. In 1985, Florida's vegetables had a value of $1.0 billion (16). Tomatoes harvested from 19,200 ha had a value of $334 million.

Although Florida's yearly rainfall normally exceeds 1.2 m, the distribution is uneven and irrigation is necessary for the successful production of most crops (22). Sprinkler and seepage (subsurface) are the most widely used methods of irrigating tomatoes. Seepage irrigation is used on the sandy flatwoods (spodic) soils of the lower east and west coasts (and on organic soils). With seepage irrigation 115-150 cm of water is supplied by lateral ditches to control the level of the water table in the field (15). Sprinkler irrigation of tomatoes requires the addition of 38-50 cm of water per crop. High yields of trickle-irrigated tomatoes grown on sandy (28) and calcareous (8) soils have been obtained with approximately

one-half of the amount of water used by the sprinkler method.

With the trickle system, water equivalent to the volume lost by evapotranspiration is applied to the soil in order to maintain the soil water content at a fairly constant level. Water is applied to a very localized portion of the cropped surface daily, or more frequently, if desired. Water loss by evaporation and percolation is reduced. In addition to a reduction in irrigation water use compared with sprinkler and subsurface methods, start-up costs are lower than with sprinkler irrigation because smaller wells and pumps are required to apply smaller water flow rates under lower pressure (29). Better conditions for harvesting and more complete disease and weed control may result because the row middles remain drier than with the other methods. Increased yields may be obtained. Another potential advantage of the use of a trickle system is greater control of the application of soluble nutrients. However, recommendations for the application of nutrients through the trickle system for the production of tomatoes (30), citrus (42,47), and other horticultural crops (7) are not precise.

CHAPTER II
FRUIT YIELD, PLANT MINERAL NUTRIENT CONCENTRATION, SOIL TEST ANALYSES, AND SHOOT PRODUCTION

Literature Review

Trickle irrigation is especially suited to arid regions due to its high efficiency of water application. With this system, crop roots are restricted primarily to a small volume of soil near the outlet of the trickle emitter, and nutrients may be readily leached from this zone due to the high frequency of water application (2,4,20, 38,40,42,48). When trickle irrigation is used on sandy soil, the potential for nutrient stress is increased due to the soil's low cation exchange capacity (50 mmol $(NH_4^+)\cdot kg^{-1}$). Even when preplant-applied slow-release N sources are used, N may have to be applied with irrigation water (14,27,30).

High yields of tomato (3), potato (43), and watermelon (44) grown with trickle-applied N have been reported. Enhanced maturity of tomato has also been observed (34). Trickle-applied N uptake by tomato has been described (3,4,24,34,45).

A continual increase in the K demand of tomato has been reported through fruitset (21,26,51). Because of the

small root systems of determinant tomato plants, potassium uptake may be suboptimal (50). Furthermore, K^+ uptake by tomato has been reported to be strongly inhibited by NH_4^+ but the K^+ effect on NH_4^+ uptake has not been documented (41).

Results of experiments with tomato (30), strawberry (28), and watermelon (13) have shown that yields were greater with approximately 60% of the N and K rate trickle-applied than yields obtained with all of the N+K applied preplant. In addition, strawberry yields with 50% trickle-applied N and K also exceeded the yield with 100% trickle-applied N and K (31).

More information regarding the proportion of preplant- and trickle-applied N and K for high yields of determinant tomatoes is needed. It has not been established whether the reported increases in yield due to trickle-applied N+K were due to the availability of N, K or N+K. Furthermore, results of a comparison of trickle-applied percentages might indicate that even higher yields could be obtained with more than 50% trickle-applied nutrient(s). The objective of this work was to examine the effect of trickle-applied N and/or K, percentage of trickle-applied nutrients (50-100%), and schedules of nutrient application (variable, 2-12.5% weekly and constant, 8.3% weekly) on the fruit yield, shoot production, and mineral nutrient concentration of leaf and shoot tissue, and mineral

nutrient concentration in the upper portion of the root zone of 'Sunny' tomatoes.

Materials and Methods

Field experiments were conducted on adjacent plots of an Arredondo fine sand (loamy, siliceous, hyperthermic, Grossarenic Paleudult) at the IFAS Horticultural Unit near Gainesville, Fla., in 1984 and 1985 (Table 2-1). Fertilizer was applied at 224-112-336-45 $kg \cdot ha^{-1}$ N-P-K-micronutrient mix. Fertilizer nutrient sources were K_2SO_4, NH_4NO_3, concentrated superphosphate (CSP), and FN 503 (Frit Industries, Ozark, Ala.). All of the CSP and FN 503 and portions of the N and K were applied broadcast and rototilled 10 cm into 20 cm high beds. Treatments were a factorial combination of fertilizer nutrients N+K and each nutrient applied individually at 50, 75, and 100% of the rate through the trickle irrigation system throughout the first 12 weeks of the growing season according to a variable (2%, week 1; 4%, week 2; 6%, week 3; 8%, week 4; 12.5%, weeks 5-8; 7.5%, weeks 9-12) and a constant (8.3% weekly) schedule of percentages of trickle-applied nutrients. A control treatment was included in which all of the N and K was preplant-applied. This is the conventional practice. There were 4 replications of each treatment.

Table 2-1. Soil-test values of samples obtained prior to fertilizer application (0-20 cm depth).

Year	pH[z]	EC ($dS \cdot m^{-1}$)	Soil mineral concentration (ppm)					
			NO_3-N	NH_4-N	P	K	Ca	Mg
1984	6.75	0.56	0.23	1.65	1.15	4.50	8.90	1.48
1985[y]	6.30	0.34	1.00	0.90	0.80	2.30	3.00	0.40

[z]EC was reported on a saturated paste extract basis whereas other soil test values were reported on 1:1 soil to water basis.
[y]Organic matter content 2% and Melich II extractable K 28 ppm.

Beds were fumigated with 252 $kg \cdot ha^{-1}$ methyl bromide (33% chloropicrin). Biwall (orifice diameter, 0.025 cm; emitter spacing, 30 cm) trickle irrigation hose (James Hardie Irrigation, El Cajon, Calif.) was placed on the soil surface at the center of the bed and then covered with black polyethylene mulch (0.0038 cm). Approximately one-month-old 'Sunny' tomatoes were transplanted on 29 March 1984 and 10 April 1985. Plants were spaced 0.45 m within rows 1.8 m apart and staked in one-row plots 10.1 m long (11,955 $plants \cdot ha^{-1}$). The volume of irrigation water applied daily was calculated weekly at 47% of the mean daily volume of the water evaporated from a U.S. Weather Service Class A pan for the previous 10-day period. Water (0.46 to 0.72 $cm \cdot day^{-1}$) was applied to the bed area (one-half the total plot area) (Table 2-2). The volume of irrigation water applied daily was reduced by rainfall in excess of 1 cm. Water was not applied following high rainfall events until it was estimated that the soil water content was less than field capacity (0.11 $mm^3 \cdot mm^{-3}$). Fertilizer was injected weekly. Injection was initiated once the maximum pressure of the system had been established. The system was flushed with irrigation water for at least 15 minutes following fertilizer injection.

Recommended commercial tomato production practices were followed (32). The fungicide chlorothalonil

Table 2-2. Evaporation (ET pan[z]), irrigation, and rainfall totals during crop production.

Water (cm)							
1984				1985			
Date	ET pan	Irrigation	Rainfall	Date	ET pan	Irrigation	Rainfall
3/29-31	0.7	1.0	0	-	-	-	-
4/1-30	12.8	5.2	9.8	4/10-30	11.3	4.8	14.0
5/1-31	18.2	9.5	20.0	5/1-30	20.3	9.4	9.0
6/1-30	18.3	9.5	4.9	6/1-30	17.2	7.1	15.3
7/1-12	7.2	3.8	5.0	7/1-9	5.4	2.5	0.5

[z]ET pan measured with a U.S. Weather Bureau Class A evaporation pan.

(Tetrachloroisoph thalonitrile) was applied at 2.2 kg·ha twice weekly. Methomyl (S-Methyl-N-((methylcarbamoyl)oxy)-thioacetimide (2.8 $l \cdot ha^{-1}$) and Bacillus thuringiensis var. kurstaki (1.1 $kg \cdot ha^{-1}$) were applied weekly to control insects.

Recently matured leaves were sampled at biweekly intervals beginning at 5 and 7 weeks after transplanting in 1984 and 1985, respectively. Above-ground portions of plants were taken following the last harvest. Tissue was dried in a forced-air drier at 70°C and ground to particles with a diameter of less than 1.6 mm. Total N was determined by the micro-Kjeldhal method using 200 mg samples (6,17). To determine P, K, Ca, and Mg concentrations, 1.0 g samples were ashed in a muffle furnace at 550°C for 8 hours. The insoluble portion of the ash was filtered and brought to a volume of 50 ml with 1N HCl. Phosphorus concentrations were determined with a Technicon Auto Analyzer. Potassium, Ca, and Mg concentrations were determined by atomic absorption spectroscopy at the IFAS Extension Soil Testing and Analytical Laboratory in Gainesville, Fla. (36).

At 9 and 13 weeks after planting, soil samples were taken at 5 (bed center) and 35 cm (bed edge) from the bed center at 0-10 and 10-20 cm depths on one side of the bed. Samples were taken between 2 and 3 m from both ends of each bed and pooled for analysis. Sampling occurred

just prior to the injection of fertilizer in both weeks (1 week after the previous fertilizer injection). Subsamples weighing 70 g were combined with 70 ml of distilled water, stirred, allowed to equilibrate for 1 hour, and filtered through No. 4 Whatman filter paper (18,23). Concentrations of NO_3-N, NH_4-N, and P in 25 ml aliquots were determined colorimetrically with a Technicon Auto Analyzer. Concentrations of K, Ca, and Mg were determined by atomic absorption spectroscopy. Solution reaction (pH) and soluble salt concentration (electrical conductivity, $dS \cdot m^{-1}$) were determined with a digital pH meter (Orion Research Model 701) and a Solu-Bridge (Industrial Instruments RD-B15), respectively.

Fruit was harvested at the beaker stage and graded according to the following mean weight categories: large, 205 g; medium, 150 g; and small, <115 g. In 1984, early season (2), midseason (1), and late season (2) fruit harvests occurred at weekly intervals beginning 12 weeks after transplanting. In 1985, there were 4 harvests (2 early, 1 midseason, and 1 late) beginning 10 weeks after transplanting.

The above-ground portion of 2 $plants \cdot plot^{-1}$ was collected after the final harvest each year. The mineral nutrient concentration of shoots was determined as previously discussed for leaf tissue.

Analyses of variance of the data and orthogonal comparisons using the SAS program were performed with the aid of the Northeast Regional Data Center computer in Gainesville, Fla.

Results

Fruit Yield

The effects of year, trickle-applied nutrients, percentage of trickle-applied nutrients, and schedule of nutrient application on fruit yield are found in this section. The effect of preplant-applied nutrients on all parameters is discussed in Chapter IV.

Year and trickle-applied nutrients interacted in their effects in the early yield of medium, large, and marketable fruit (Table 2-3). In 1984, the yield of fruit in these categories was higher with trickle-applied K than with trickle-applied N or N+K (Table 2-4). In 1985, there were no significant differences due to trickle-applied nutrients.

Early yield of large fruit decreased linearly from 15.8 to 11.6 $t \cdot ha^{-1}$ with an increase in the trickle-applied percentage of nutrients (Table 2-3). Trickle-applied nutrients and trickle-applied percentage of nutrients interacted in their effects on the yield of early medium and marketable fruit (Table 2-5). Similar linear decreases in yield were obtained within size categories as the trickle-applied percentage of N+K and N increased. The

Table 2-3. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on the early yield of fruit.

	Yield (t·ha^{-1})				
	Size[z]				
Treatment	Large	Medium	Small	Marketable	Cull
Year (Yr)					
1984	16.5	8.6	2.1	27.1	1.8
1985	11.4	5.3	2.3	19.0	1.3
Signif.[y]	*	***	NS	*	*
Nutrients applied (NUT)					
N+K	12.6b[x]	6.1b	2.1	20.8b	1.3
N	13.6ab	6.2b	1.9	21.7b	1.6
K	15.6a	8.5a	2.6	26.7a	1.6
Yr x NUT	*	**	NS	***	NS
Trickle-applied (%)					
50	15.8	7.8	2.4	26.1	1.6
75	14.4	6.9	2.2	23.5	1.5
100	11.6	6.1	1.9	19.6	1.5
Signif.	L***	NS	NS	L***	NS
NUT x %	NS	*	NS	*	NS
Yr x NUT x %	NS	NS	*	NS	**
Schedule					
Variable	14.2	7.4	2.2	23.7	1.5
Constant	13.7	6.5	2.2	22.4	1.5
Signif.	NS	*	NS	NS	NS

[z]Mean fruit weights were large, 205 g; medium, 150 g; and small, <115 g.
[y]Main effects or interactions were significant at the 5% (*), 1% (**), 0.1% (***) level or nonsignificant (NS). Significant responses to percentage of nutrients trickle-applied were linear (L).
[x]Mean separation by Duncan's multiple range test, 5% level.

Table 2-4. Interaction of year and trickle-applied nutrients on the early yield of large, medium, and total marketable fruit.

	Yield ($t \cdot ha^{-1}$)		
	Nutrients applied		
Year	N+K	N	K
		Medium	
1984	7.1b[z]	7.4b	11.3a
1985	5.1	5.1	5.7
		Large	
1984	14.1b	15.6b	19.6a
1985	11.0	11.6	11.6
		Marketable	
1984	23.0b	24.5b	33.8a
1985	18.5	18.9	19.6

[z]Mean separation within years by Duncan's multiple range test, 5% level.

Table 2-5. Interaction of trickle-applied nutrients and percentage of nutrients trickle-applied on the early yield of medium and marketable fruit.

Nutrients applied	Yield ($t \cdot ha^{-1}$) Trickle-applied (%) 50	75	100	Signif.[z]
		Medium		
N+K	7.8	5.9	4.6	L***
N	7.3	6.5	4.9	L**
K	8.3	8.2	8.9	NS
		Marketable		
N+K	26.4	20.4	15.5	L***
N	24.3	23.6	17.2	L**
K	27.4	26.2	26.2	NS

[z]Effects were linear at the 1% (L**) or 0.1% (L***) level or nonsignificant (NS). Interactions for medium fruit were significant for N+K vs K x trickle-applied percentage of nutrients L (*) and N vs K x trickle-applied percentage of nutrients L (5% level). The interaction for total marketable fruit was significant for N+K vs K x trickle-applied percentage of nutrients L at the 1% level.

decrease in total marketable yield obtained with trickle-applied N+K but not with N was significantly different from the yield obtained when K was injected. Year, trickle-applied nutrients, and trickle-applied percentage of nutrients interacted in their effects on the yield of small fruit and culls (Table 2-6). In 1984, the linear decrease in the yield of small fruit and culls obtained as the percentage of trickle-applied N+K and N increased was significantly different from the response obtained when K was trickle-applied. In 1985, the interactions were not significant.

At midseason, trickle-applied nutrients and trickle-applied percentage of nutrients interacted in their effects on yield of large fruit (Table 2-7). When N+K was injected, a quadratic yield response to the trickle-applied percentage was obtained with the highest yield (12.5 $t \cdot ha^{-1}$) at 75% trickle-applied nutrients (Table 2-8). When N was injected, the yield of large fruit decreased linearly from 14.0 to 9.7 $t \cdot ha^{-1}$. Significant differences due to trickle-applied percentage were not obtained when K was injected. Year and trickle-applied nutrients interacted in their effects on the yield of medium fruit (Table 2-9). Significant yield differences were not obtained due to trickle-applied nutrients in 1984 but in 1985 the yield obtained when N was trickle-applied (7.7 $t \cdot ha^{-1}$) was significantly higher than the yield obtained when N+K was

Table 2-6. Interaction of year, trickle-applied nutrients, and percentage of nutrients trickle-applied on the early yield of small fruit and culls.

Nutrients applied	Yield ($t \cdot ha^{-1}$) 1984 Trickle-applied (%) 50	75	100	Signif.[z]	1985 Trickle-applied (%) 50	75	100	Signif.
Small								
N+K	2.4	1.7	1.1	L***	3.0	2.6	1.7	NS
N	1.8	1.8	1.0	L*	2.0	1.7	2.8	NS
K	2.8	2.6	3.4	NS	2.6	2.7	1.6	NS
Culls								
N+K	2.2	1.3	1.2	L**	0.9	1.1	1.1	NS
N	2.3	2.0	1.3	L**	1.1	1.4	1.3	NS
K	1.4	2.0	2.2	L*	1.4	1.3	1.6	NS

[z]Responses to percentage of nutrients trickle-applied were linear (L) at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS). Interactions for small fruit and culls were significant for N+K vs K x trickle-applied percentage of nutrients L (***) and N vs K x trickle-applied percentage of nutrients L (**).

Table 2-7. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on the midseason yield of fruit.

	Yield ($t \cdot ha^{-1}$)				
	Size[z]				
Treatment	Large	Medium	Small	Marketable	Cull
Year (Yr)					
1984	13.3	6.6	3.6	23.5	0.7
1985	8.7	6.2	5.9	20.8	1.1
Signif.[y]	NS	NS	**	NS	*
Nutrients applied (NUT)					
N+K	10.4b[x]	5.7	4.1b	20.2b	0.8
N	12.1a	6.9	5.2a	24.1a	0.9
K	10.5b	6.6	4.9ab	21.9ab	1.0
Yr x NUT	NS	*	NS	NS	NS
Trickle-applied (%)					
50	11.3	6.4	4.7	22.4	0.8
75	11.9	6.7	5.1	23.7	1.0
100	9.8	6.1	4.4	20.2	0.9
Signif.	L*Q*	NS	NS	Q*	NS
NUT x %	**	NS	NS	NS	NS
Schedule (S)					
Variable	11.1	6.8	7.7	22.6	0.9
Constant	10.9	6.0	4.7	21.6	0.9
Signif.	NS	NS	NS	NS	NS
NUT x S	NS	*	NS	NS	NS

[z]Mean fruit weights were large, 205 g; medium, 150 g; and small, <115 g.
[y]Main effects or interactions were significant at the 5% (*) or 1% (**) level or nonsignificant (NS). The significant response to percentage of nutrients trickle-applied was linear (L) or quadratic (Q).
[x]Mean separation by Duncan's multiple range test, 5% level.

Table 2-8. Interaction of trickle-applied nutrients and percentage of nutrients trickle-applied on the midseason yield of large fruit.

Nutrients applied	Yield ($t \cdot ha^{-1}$) Trickle-applied (%) 50	75	100	Signif.[z]
N+K	10.1	12.5	8.6	L**Q**
N	14.0	12.5	9.7	L***
K	9.8	10.8	10.9	NS

[z]Effects were linear (L) or quadratic (Q) at the 1% (**) or 0.1% (***) level or nonsignificant (NS).

Table 2-9. Interaction of year and trickle-applied nutrients on the midseason yield of medium fruit.

Year	Yield ($t \cdot ha^{-1}$) Nutrients applied N+K	N	K
1984	6.5	6.2	7.1
1985	5.0b[z]	7.7a	6.0ab

[z]Mean separation within years by Duncan's multiple range test, 5% level.

injected (5.0 $t \cdot ha^{-1}$) but not significantly different than when K was injected (6.0 $t \cdot ha^{-1}$). Trickle-applied nutrients and schedule of nutrient application interacted in their effects on the yield of large fruit (Table 2-10). The yield of small and marketable fruit at midseason was higher when N was trickle-applied than when N+K was trickle-applied but not significantly higher than when K was trickle-applied (Table 2-7). The response of the yield of total marketable fruit to the percentage of nutrients trickle-applied was quadratic.

The late yield of marketable fruit was significantly higher in 1985 (37.0 $t \cdot ha^{-1}$) than in 1984 (14.7 $t \cdot ha^{-1}$) mainly because of the greater yield (19.7 $t \cdot ha^{-1}$) of small fruit (Table 2-11). Year, trickle-applied nutrients, and percentage of nutrients trickle-applied interacted in their effects on the yield of medium fruit (Table 2-12). Linear increases in the yield of large and total marketable fruit were obtained with an increase in the trickle-applied percentage of nutrients (Table 2-11).

The total yield of large fruit was greater in 1984 than in 1985 but the total yield of small and marketable fruit was greater in 1985 than in 1984 (Table 2-13). Year and trickle-applied percentage of nutrients interacted in their effects on the yield of large and marketable fruit (Table 2-14). Yield of fruit in both categories changed quadratically with an increase in trickle-applied

Table 2-10. Interaction of trickle-applied nutrients and schedule of nutrient application on the midseason yield of large fruit.

Schedule	Yield ($t \cdot ha^{-1}$) Nutrients applied N+K	N	K
Variable	5.9b^{z}	8.2a	6.4b
Constant	5.6	5.6	6.7

^{z}Mean separation within schedules by Duncan's multiple range test, 5% level.

Table 2-11. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on the late yield of fruit.

	Yield ($t \cdot ha^{-1}$)				
	Size[z]				
Treatment	Large	Medium	Small	Marketable	Cull
Year (Yr)					
1984	5.3	5.0	4.4	14.7	-
1985	6.0	9.5	21.5	37.0	1.6
Signif.[y]	NS	***	***	***	-
Nutrients applied (NUT)					
N+K	6.7	8.9a	12.8	28.3	0.8
N	5.4	6.6b	15.1	27.1	0.7
K	5.0	6.3b	11.0	22.2	0.8
Trickle-applied (%)					
50	5.0	7.3	11.6	23.9	0.7
75	5.6	7.2	12.3	25.1	0.8
100	6.5	7.2	14.9	28.7	0.8
Signif.	LX	NS	NS	LX	NS
Yr x NUT x %	NS	**	NS	NS	NS
Schedule					
Variable	5.9	6.8	13.4	26.1	0.8
Constant	5.5	7.7	12.5	25.6	0.8
Signif.	NS	NS	NS	NS	NS

[z]Mean fruit weights were large, 205 g; medium, 150 g; and small, <115 g.
[y]Main effects or interactions were significant at the 15% (X), 1% (**), or 0.1% (***) level or nonsignificant (NS). Significant responses to percentage of nutrients trickle-applied were linear (L).

Table 2-12. Interaction of year, trickle-applied nutrients, and percentage of nutrients trickle-applied on the late yield of medium fruit.

Nutrients injected	Yield ($t \cdot ha^{-1}$) 1984 Trickle-applied (%) 50	75	100	Signif.[z]	1985 Trickle-applied (%) 50	75	100	Signif.
N+K	5.6	7.1	6.0	NS	13.6	4.2	11.5	Q*
N	5.7	8.9	4.5	NS	7.6	9.2	7.8	NS
K	3.9	3.9	3.3	NS	7.4	8.8	10.3	NS

[z]Responses to percentage of nutrients trickle-applied were quadratic at the 5% (Q*) or not significant (NS).

Table 2-13. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on the total yield of fruit.

	Yield ($t \cdot ha^{-1}$)				
	Size[z]				
Treatment	Large	Medium	Small	Marketable	Cull
Year (Yr)					
1984	35.1	20.3	10.0	65.3	2.4
1985	26.1	21.0	29.7	76.8	3.9
Signif.[y]	*	NS	***	**	*
Nutrients applied (NUT)					
N+K	29.7	20.7	19.0	69.3	2.9
N	31.1	19.7	22.1	73.0	3.2
K	31.1	21.3	18.5	70.8	3.4
Signif.	NS	NS	NS	NS	NS
Trickle-applied (%)					
50	32.1	21.5	18.8	72.4	3.1
75	31.9	20.8	19.6	72.3	3.3
100	27.8	19.4	21.2	68.5	3.2
Signif.	L*	L*	NS	NS	NS
Yr x %	*	NS	NS	*	NS
NUT x %	*	NS	NS	NS	NS
Yr x NUT x %	NS	NS	NS	NS	*
Schedule (S)					
Variable	31.1	21.0	20.4	72.4	3.2
Constant	30.1	20.1	19.4	69.6	3.1
Signif.	NS	NS	NS	NS	NS
NUT x S	NS	*	NS	NS	NS

[z]Mean fruit weights were large, 205 g; medium, 150 g; and small, <115 g.

[y]Main effects or interactions were significant at the 5% (*), 1% (**), 0.1% (***) level or nonsignificant (NS). The significant response to percentage of nutrients trickle-applied was linear (L).

Table 2-14. Interaction of year and percentage of nutrients trickle-applied on the total yield of large and marketable fruit.

Size category	Yield ($t \cdot ha^{-1}$) Trickle-applied (%) 50	75	100	Signif.[z]
Large				
1984	38.3	37.2	38.3	L***Q**
1985	26.0	26.5	26.0	NS
Marketable				
1984	69.3	68.9	57.7	L***Q**
1985	75.4	75.7	79.9	NS

[z]Responses to percentage of nutrients trickle-applied were linear at the 0.1% level (L***), quadratic at the 1% level (Q**), or nonsignificant NS).

percentage of nutrients in 1984 but in 1985 significant changes in yield were not obtained. Trickle-applied nutrients and percentage of nutrients trickle-applied interacted in their effects on the total yield of large fruit (Table 2-15). Similar significant linear decreases in yield were obtained as the trickle-applied percentage of nutrients increased when N+K and N were trickle-applied but a significant difference in yield was not obtained when K was injected. The total yield of medium fruit decreased linearly with an increase in trickle-applied percentage of nutrients (Table 2-13). Trickle-applied nutrients and schedule of nutrient application interacted in their effects on the total yield of medium fruit (Table 2-16). Year, trickle-applied nutrients, and percentage of trickle-applied nutrients interacted in their effects on total yield of culls (Table 2-17).

Leaf and Shoot Mineral Nutrient Concentration

In 1984, 5 weeks after transplanting, trickle-applied nutrients and percentage of nutrients trickle-applied interacted in their effects on leaf N concentration (Table 2-18). When N+K and N were injected, similar linear decreases in leaf N concentration were obtained as the percentage of trickle-applied nutrients increased (Table 2-19). Both linear trends were significantly different from the nonsignificant effect of percentage of trickle-applied K on leaf N concentration. At 7 weeks after

Table 2-15. Interaction of trickle-applied nutrients and percentage of nutrients trickle-applied on the total yield of large fruit.

Nutrients applied	Yield ($t \cdot ha^{-1}$) Trickle-applied (%) 50	75	100	Signif.[z]
N+K	31.9	31.7	25.4	L*
N	34.7	33.7	24.9	L**
K	29.8	30.3	33.2	NS

[z]Responses to percentage of nutrients trickle-applied were linear (L) at the 5% (*) or 1% (**) level or nonsignificant (NS). Interactions were significant for N+K vs K x trickle-applied percentage L (*) and N vs K x trickle-applied percentage of nutrients L (**).

Table 2-16. Interaction of trickle-applied nutrients and schedule of nutrient application on the total yield of medium fruit.

Schedule	Yield ($t \cdot ha^{-1}$) Nutrients applied N+K	N	K
Variable	20.9	21.5	20.7
Continuous	20.5a[z]	18.0b	21.8a

[z]Mean separation within schedules by Duncan's multiple range test, 5% level.

Table 2-17. Interaction of year, trickle-applied nutrients, and percentage of nutrients trickle-applied on the total yield of culls.

	Yield ($t \cdot ha^{-1}$)							
	1984				1985			
Nutrients	Trickle-applied (%)				Trickle-applied (%)			
injected	50	75	100	Signif.[z]	50	75	100	Signif.
N+K	2.9	2.1	1.8	L**	2.7	4.1	4.1	NS
N	3.0	2.8	2.1	L**	3.1	4.3	3.8	NS
K	1.9	2.6	2.8	L*	4.9	4.8	4.4	NS

[z]Responses to percentage of nutrients trickle-applied were linear (L) at the 5% (*) or 1% (** level or nonsignificant (NS). Interactions were significant in 1984 for N+K vs K x trickle-applied percentage of nutrients L (0.01% level) and for N vs K x trickle-applied percentage of nutrients L**.

Table 2-18 Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on leaf and shoot N concentration.

	N concn (%)					
	Leaf sampled at week after transplanting					
Treatment	5	7	9	11	13	Shoot[z]
Year (Yr)						
1984	6.04	5.37	5.39	5.35	4.31	2.15
1985	-	4.35	4.39	4.08	3.84	2.21
Signif.[y]	-	***	NS	*	*	NS
Nutrients applied (NUT)						
N+K	5.75b	4.77	4.80	4.89a	4.11b	2.09b
N	5.82b	4.89	5.00	4.92a	4.30a	2.22a
K	6.56a	4.92	4.88	4.33b	3.82c	2.21a
Yr x NUT	NS	NS	NS	NS	***	NS
Trickle-applied (%)						
50	6.22	4.78	4.80	4.53	4.08	2.19
75	6.04	4.98	4.92	4.74	3.94	2.11
100	5.86	4.86	4.96	4.86	4.19	2.23
Signif.	L***	NS	NS	L***	Q**	Q*
NUT x %	X	NS	NS	NS	NS	NS
Schedule (S)						
Variable	6.04	4.92	4.96	4.75	4.07	2.18
Constant	6.04	4.80	4.82	4.68	4.07	2.17
NUT x S	NS	*	NS	NS	NS	*

[z] Taken at 17 and 14 weeks after transplanting in 1984 and 1985, respectively.

[y] Main effects or interactions were significant at the 7% (X), 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS). Significant responses to percentage of nutrients trickle-applied were linear (L) or quadratic (Q).

Table 2-19. Interaction of trickle-applied nutrients and percentage of nutrients trickle-applied on shoot and leaf mineral nutrient concentrations.

Nutrients applied	Nutrient concn (%) Trickle-applied (%) 50	75	100	Signif.[z]
		Leaf N at 5 wks		
N+K	6.08	5.71	5.46	L**[y]
N	6.09	5.84	5.53	L**
K	6.52	6.58	6.58	NS
		Leaf K at 5 wks		
N+K	2.52	2.49	2.24	L**[x]
N	2.58	2.58	2.46	NS
K	2.64	2.44	2.14	L***
		Leaf K at 11 wks		
N+K	1.76	1.78	1.83	NS[w]
N	1.26	1.21	1.03	L**
K	1.59	1.55	1.56	NS
		Leaf Ca at 11 wks		
N+K	2.20	2.36	2.49	L*[v]
N	2.30	2.32	3.00	L**
K	2.41	2.39	2.18	NS
		Shoot Ca		
N+K	3.28	3.34	3.71	L***
N	3.34	3.43	3.96	L***Q*
K	3.29	3.24	3.28	NS
		Leaf Mg at 5 wks		
N+K	0.36	0.38	0.39	L*
N	0.37	0.37	0.39	NS
K	0.36	0.32	0.34	Q**

[z]Responses to percentage of nutrients trickle-applied were linear (L) or quadratic (Q) at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS).

[y]Interactions for N concentrations at 5 weeks were significant for N+K vs K x trickle-applied percentage of nutrients L (**) and N vs K x trickle-applied percentage of nutrients L (*).

[x]The interaction for K concentrations at 5 weeks were significant for N vs K x trickle-applied percentage of nutrients L (**).

Table 2-19--continued.

[w]The interaction for K concentration at 11 weeks was significant for N+K vs N x trickle-applied percentage of nutrients L (*).

[u]The interaction for Ca concentration at 11 weeks was significant for N+K vs N x trickle-applied percentage of nutrients L (*).

transplanting the effect of trickle-applied nutrients interacted with the schedule of nutrient application in their effects on leaf N concentration (Table 2-20). Significant differences in N concentration due to trickle-applied nutrients were not obtained at 9 weeks (Table 2-18) but at 11 weeks in both years and at 13 weeks in 1984 (Table 2-21) N concentrations were higher when N+K and N were injected than when K was injected. Significant changes in N concentration due to trickle-applied percentage of nutrients were not obtained at 7 and 9 weeks but at 11 and 13 weeks linear and quadratic trends, respectively, were obtained (Table 2-18).

At 5 weeks in 1984, 7 weeks in both years (Table 2-22), and at 9 and 11 weeks in 1985 (Table 2-21), leaf P concentrations were not significantly affected by trickle-applied nutrients. From 9 through 13 weeks in 1984, but not in 1985, leaf P concentrations were usually higher with trickle-applied N+K and/or N than with trickle-applied K.

Five weeks after transplanting in 1984 trickle-applied nutrients and trickle-applied percentage of nutrients interacted in their effects on leaf K concentrations (Table 2-23). Similar linear decreases in leaf K concentration were obtained when N+K and K were trickle-applied but significant differences were not obtained when N was injected (Table 2-19). The linear trend obtained with

Table 2-20. Interaction of trickle-applied nutrients and schedule of nutrient application on leaf and shoot N concentration.

	N concn (%)		
	Nutrients applied		
Schedule	N+K	N	K
		Leaf N 7 wks	
Variable	4.91	5.01	4.83
Constant	4.62b[z]	4.77ab	5.02a
		Shoot N	
Variable	2.08b	2.32a	2.16ab
Constant	2.11	2.14	2.26

[z]Mean separation within schedules by Duncan's multiple range test, 5% level.

Table 2-21. Interaction of year and trickle-applied nutrients on leaf N, P, K, and Mg concentrations.

Year	Leaf nutrient concn (%)		
	Nutrients applied		
	N+K	N	K
		N at 13 wks	
1984	4.46a[z]	4.59a	3.88b
1985	3.75b	4.00a	3.75b
		P at 9 wks	
1984	0.29ab	0.32a	0.28b
1985	0.27	0.26	0.26
		P at 11 wks	
1984	0.29a	0.32a	0.26b
1985	0.23	0.22	0.21
		P at 13 wks	
1984	0.30b	0.34a	0.30b
1985	0.20b	0.22a	0.22a
		K at 7 wks	
1984	2.24a	1.96b	1.99b
1985	2.13	2.06	1.96
		K at 13 wks	
1984	1.90a	1.09b	1.75a
1985	0.99b	0.78c	1.25a
		Mg at 9 wks	
1984	0.42b	0.46a	0.39c
1985	0.54b	0.60a	0.57ab

[z]Mean separation within years by Duncan's multiple range test, 5% level.

Table 2-22. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on leaf and shoot P concentration.

	P concn (%)					
	Leaf sampled at week after transplanting					
Treatment	5	7	9	11	13	Shoot[z]
Year (Yr)						
1984	0.46	0.36	0.30	0.29	0.31	0.48
1985	-	0.31	0.26	0.22	0.21	0.21
Signif.[y]	-	***	*	**	***	***
Nutrients applied (NUT)						
N+K	0.46	0.34	0.28ab	0.26a	0.25b	0.34
N	0.44	0.34	0.29a	0.27a	0.28a	0.37
K	0.43	0.34	0.27b	0.24b	0.26b	0.35
Yr x NUT	NS	NS	*	**	*	NS
Trickle-applied (%)						
50	0.44	0.33	0.27	0.25	0.27	0.33
75	0.44	0.34	0.28	0.26	0.25	0.36
100	0.44	0.34	0.29	0.26	0.26	0.36
Signif.	NS	NS	NS	NS	NS	L*
Schedule (S)						
Variable	0.43	0.33	0.28	0.25	0.26	0.34
Constant	0.45	0.35	0.28	0.26	0.26	0.36
Signif.	NS	NS	NS	NS	NS	*
Yr x S	NS	NS	NS	NS	NS	***

[z]Taken at 17 and 14 weeks after transplanting in 1984 and 1985, respectively.
[y]Main effects or interactions were significant at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS). Significant responses to percentage of nutrients trickle-applied were linear (L).

Table 2-23. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on leaf and shoot K concentration.

Treatment	K concn (%) Leaf sampled at week after transplanting 5	7	9	11	13	Shoot[z]
Year (Yr)						
1984	2.46	2.05	2.20	1.82	1.58	2.34
1985	-	2.05	1.41	1.19	1.00	1.58
Signif.[y]	-	NS	***	***	**	**
Nutrients applied (NUT)						
N+K	2.42b	2.18a	2.00a	1.77a	1.44a	2.17a
N	2.54a	1.99b	1.64c	1.17c	0.93b	1.62b
K	2.40b	1.98b	1.79b	1.57b	1.50a	2.10a
Yr x NUT	NS	*	NS	NS	***	NS
Trickle-applied (%)						
50	2.57	2.10	1.86	1.52	1.31	2.06
75	2.50	2.07	1.80	1.52	1.30	1.99
100	2.28	1.98	1.76	1.47	1.27	1.84
Signif.	L***	L*	L*	NS	NS	L
Yr x %	NS	NS	***	NS	NS	NS
NUT x %	X	NS	NS	*	NS	NS
Schedule						
Variable	2.45	2.05	1.83	1.53	1.28	2.00
Constant	2.46	2.05	1.79	1.48	1.31	1.92
Signif.	NS	NS	NS	NS	NS	NS

[z]Taken at 17 and 14 weeks after transplanting in 1984 and 1985, respectively.
[y]Main effects or interactions were significant at the 7% (X), 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS). Significant responses to percentage of nutrients trickle-applied were linear (L).

trickle-applied K differed significantly from the effect of trickle-applied N. At 7 (in 1984 (Table 2-21)), 9, 11, and 13 (Table 2-23) weeks after transplanting, leaf K concentrations were higher when N+K and/or K were trickle-applied than when N was trickle-applied. This response was also obtained with shoot tissue. Linear decreases in leaf K concentration were obtained at 7 weeks after transplanting (Table 2-23), at 9 weeks in 1984 (Table 2-24), and in shoot tissue (Table 2-23).

Leaf and plant Ca (Tables 2-25, 2-26, and 2-27) and Mg (Table 2-28) concentrations were also obtained.

Soil Test Analyses

Nine weeks after transplanting, soluble salt concentrations in the soil solution in the edge of the bed were higher when both N and K were trickle-applied individually than when both nutrients were trickle-applied together (Table 2-29). Concentrations of N and K were lower when the respective nutrient was trickle-applied than when the other nutrient was trickle-applied. Concentrations of Ca were higher when N was trickle-applied than when N+K was injected but not consistently higher than when K was injected (Table 2-30). Concentrations of NO_3-N and NH_4-N decreased quadratically and linearly, respectively, whereas the P concentration increased linearly with an increase in trickle-applied percentage of nutrients (Table 2-29). Linear increases in soil solution

Table 2-24. Interaction of year and percentage of nutrients trickle-applied on leaf K and Ca concentrations 9 weeks after transplanting.

Year	Leaf nutrient concn (%) 50	75	100	Signif.[z]
		K		
1984	2.34	2.22	2.05	L***
1985	1.38	1.39	1.47	NS
		Ca		
1984	1.64	1.79	1.91	L***
1985	2.31	2.49	2.31	Q*

[z]Responses to percentage of nutrients trickle-applied were linear at the 0.1% level (L***), quadratic at the 5% level (Q*), or nonsignificant (NS).

Table 2-25. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on leaf and shoot Ca concentration.

Treatment	Ca concn (%)					
	Leaf sampled at week after transplanting					
	5	7	9	11	13	Shoot[z]
Year (Yr)						
1984	1.81	1.63	1.78	2.62	3.40	3.95
1985	-	1.44	2.37	2.26	1.81	2.91
Signif.[y]	-	**	***	**	***	***
Nutrients applied (NUT)						
N+K	1.92a	1.52	1.97b	2.35	2.54b	3.44a
N	1.84a	1.55	2.20a	2.64	2.76a	3.58b
K	1.66b	1.54	2.05b	2.33	2.52b	3.27a
Trickle-applied (%)						
50	1.72	1.41	1.98	2.31	2.56	3.31
75	1.78	1.57	2.13	2.45	2.61	3.34
100	1.93	1.62	2.11	2.56	2.65	3.65
Signif.	L***	L***	L**Q*	L**	NS	L***Q*
Yr x %	NS	NS	*	NS	NS	NS
NUT x %	NS	NS	NS	**	NS	**
Yr x NUT x %	NS	**	NS	NS	NS	NS
Schedule (S)						
Variable	1.79	1.56	2.11	2.48	2.58	3.45
Constant	1.83	1.51	2.05	2.40	2.64	3.40
Signif.	NS	NS	NS	NS	NS	NS
Yr x NUT x S	NS	NS	NS	*	*	NS

[z]Taken at 17 and 14 weeks after transplanting in 1984 and 1985, respectively.
[y]Main effects or interactions were significant at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS). Significant responses to percentage of nutrients trickle-applied were linear (L) or quadratic (Q).

Table 2-26. Interaction of year, trickle-applied nutrients, and percentage of nutrients trickle-applied on leaf Ca and Mg concentrations 7 weeks after transplanting.

Nutrients applied	Leaf nutrient concn (%) 1984 Trickle-applied (%) 50	75	100	Signif.	1985 Trickle-applied (%) 50	75	100	Signif.
				Ca^{z}				
N+K	1.46	1.77	1.77	L***Q*	1.28	1.43	1.41	NS
N	1.43	1.50	1.89	L***Q*	1.53	1.47	1.53	NS
K	1.60	1.64	1.69	NS	1.24	1.63	1.46	Q*
				Mg				
N+K	0.40	0.43	0.42	NS	0.41	0.43	0.41	NS
N	0.37	0.40	0.42	NS	0.48	0.48	0.46	NS
K	0.41	0.40	0.40	L*	0.41	0.49	0.45	NS

[z]Interactions for Ca concentration in 1984 were significant for N+K vs N x trickle-applied percentage of nutrients quadratic at the 1% level (Q*) and in 1985 for N vs K x trickle-applied percentage of nutrients linear at the 5% level (L*).

Table 2-27. Interactions of year, trickle-applied nutrients, and schedule of nutrients trickle-applied on leaf Ca and Mg concentration at 11 and 13 weeks after transplanting.

Nutrients applied	Nutrient conc (%)			
	1984		1985	
	Schedule			
	Variable	Constant	Variable	Constant
	Ca at 11 wks			
N+K	2.50b[z]	2.55ab	2.23b	2.13a
N	2.86a	2.82a	2.73a	2.16a
K	2.26b	2.45b	2.01b	2.29a
	Ca at 13 wks			
N+K	3.28	3.18b	1.66b	2.04a
N	3.45	3.55a	2.14a	1.86ab
K	3.32	3.58a	1.58b	1.60b
	Mg at 11 wks			
N+K	0.41b	0.40b	0.44b	0.43a
N	0.45a	0.45a	0.55a	0.46a
K	0.39b	0.38b	0.44b	0.46a

[z]Mean separation within schedules by Duncan's multiple range test, 5% level.

Table 2-28. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on leaf and shoot Mg concentration.

Treatment	Mg concn (%)					
	Leaf sampled at week after transplanting					
	5	7	9	11	13	Shoot[z]
Year (Yr)						
1984	0.36	0.41	0.42	0.41	0.44	0.64
1985	-	0.45	0.57	0.46	0.44	0.86
Signif.[y]	-	***	***	***	NS	***
Nutrients applied (NUT)						
N+K	0.37a	0.42	0.48	0.42b	0.44b	0.73b
N	0.37a	0.44	0.53	0.48a	0.47a	0.81a
K	0.34b	0.43	0.48	0.42b	0.41c	0.70b
Yr x NUT	NS	NS	*	NS	NS	NS
Trickle-applied (%)						
50	0.36	0.42	0.50	0.43	0.45	0.73
75	0.35	0.44	0.51	0.44	0.43	0.75
100	0.37	0.43	0.49	0.44	0.44	0.77
Signif.	Q*	Q*	NS	NS	NS	L**
N x %	**	NS	NS	NS	NS	NS
Yr x NUT x %	NS	*	NS	NS	NS	NS
Schedule (S)						
Variable	0.36	0.43	0.50	0.45	0.44	0.76
Constant	0.36	0.42	0.50	0.43	0.44	0.74
Signif.	NS	NS	NS	NS	NS	NS
Yr x NUT x S	NS	NS	NS	*	NS	NS

[z]Taken at 17 and 14 weeks after transplanting in 1984 and 1985, respectively.
[y]Main effects or interactions were significant at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS). Significant responses to percentage of nutrients trickle-applied were linear (L) or quadratic (Q).

Table 2-29. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on soil test values 9 weeks after transplanting. Bed edge 0-10 cm.

Treatment	pH	Soluble salts ($dS \cdot m^{-1}$)	Soil mineral concn (ppm) NO_3-N	NH_4-N	P	K	Ca	Mg
Year (Yr)								
1984	6.04	2.08	12.5	3.67	1.26	25.5	46.8	4.44
1985	5.30	3.05	27.5	19.1	0.27	52.0	42.6	12.20
Signif.[z]	**	NS	NS	**	***	NS	NS	*
Nutrients applied (NUT)								
N+K	5.69a[y]	1.70b	12.7b	6.08b	0.89a	19.9b	25.1b	6.85b
N	5.74a	3.16a	13.6b	7.45b	0.75ab	76.6a	42.2a	9.57a
K	5.68b	2.83a	33.6a	20.67a	0.64b	19.8b	36.8a	8.61a
Yr x NUT	NS	NS	NS	NS	NS	NS	*	NS
Trickle-applied (%)								
50	5.69	2.97	29.2	16.25	0.64	45.5	36.6	8.75
75	5.69	2.45	14.8	9.79	0.80	38.8	36.6	8.93
100	5.63	2.28	16.0	8.15	0.84	32.0	31.0	7.36
Signif.	**L	NS	L**Q*	L*	L*	L*	NS	NS
NUT x %	NS	NS	NS	NS	NS	*	NS	NS
Schedule								
Variable	5.67	2.55	18.3	11.5	0.75	3.81	34.0	3.09
Constant	5.67	2.58	21.7	11.3	0.77	3.94	35.5	8.60
Signif.	NS	NS	NS	NS	NS	NS	NS	NS

[z]Main effects or interactions were significant at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS). Significant responses to the percentage of nutrients trickle-applied were linear (L) or quadratic (Q).
[y]Mean separation by Duncan's multiple range test, 5% level.

Table 2-30. Interaction of year and trickle-applied nutrients on soil mineral concentrations 9 weeks after transplanting.

Location and depth in bed		Year	Soil mineral concn (ppm) Nutrients applied N+K	N	K
				Ca	
Edge	0-10 cm	1984	14.70b[z]	31.16a	34.62a
		1985	35.40b	53.33a	38.92b
				P	
Edge	10-20 cm	1984	1.33ab	1.47a	1.15b
		1985	0.13	0.19	0.16
				K	
		1984	5.10b	14.88a	4.26b
		1985	0.13	0.19	0.16
				Ca	
		1984	8.13b	8.98ab	11.23a
		1985	17.43a	16.83a	12.20b
				Mg	
		1984	1.05b	1.15ab	1.50a
		1985	5.36	4.68	3.34
				NH_4-N	
Center	0-10 cm	1984	0.26	0.17	0.47
		1985	1.36b	2.25b	4.51a
				K	
		1984	10.03	5.88	9.64
		1985	12.78b	21.54a	23.38a
				NO_3-N	
Center	10-20 cm	1984	4.52	2.00	11.88
		1985	9.84ab	16.30a	7.88b
				Ca	
		1984	7.25	6.24	6.44
		1985	16.80a	15.89a	9.38b
				Mg	
		1984	0.90	0.95	0.76
		1985	3.15	3.54	2.09

[z]Mean separation within years by Duncan's multiple test range, 5% level.

K concentrations were obtained as the trickle-applied percentage increased when N+K and K were injected but not when N was injected (preplant-applied K) (Table 2-31).

Soluble salt concentrations in the upper portion (0-10 cm depth) of the center of the bed were also significantly higher when N and K were trickle-applied individually than when both nutrients were trickle-applied together (Table 2-32). Significant effects of trickle-applied nutrients were not obtained on the concentration of NO_3-N in both years and on NH_4-N and K concentrations in 1984 (Table 2-30). Trickle-applied nutrients and trickle-applied percentage of nutrients interacted in their effects on the NO_3-N concentration. The concentration of NO_3-N decreased linearly as the percentage of trickle-applied K increased but significant changes in concentration were not obtained when N+K or N was injected (Table 2-31). A linear decrease in NH_4-N and a linear increase in P concentrations were obtained with an increase in trickle-applied percentage of nutrients (Table 2-32).

Soil N and soluble salt concentrations at 10-20 cm in the bed edge were not significantly affected by trickle-applied nutrients (Table 2-33). The concentration of K was significantly higher when K was preplant-applied (trickle-applied N) than when N+K and K were injected only in 1984 (Table 2-30). In 1985, significant effects of trickle-applied nutrients were not obtained. Small but significant

Table 2-31. Interaction of trickle-applied nutrients and percentage of nutrients trickle-applied on soil test values 9 weeks after transplanting.

Location and depth in bed	Nutrients applied	Soil test value Trickle-applied (%) 50	75	100	Signif.[z]
			K (ppm)		
Edge 0-10 cm	N+K	6.50	16.61	36.62	L**[y]
	N	81.80	81.23	65.84	NS
	K	6.73	18.52	34.21	L*
			NO_3-N (ppm)		
Center 0-10 cm	N+K	5.65	4.79	3.11	NS
	N	6.98	4.73	8.43	NS
	K	4.03	4.85	14.18	L***
			pH		
Center 10-20 cm	N+K	5.51	5.79	5.85	L***[x]
	N	5.32	5.76	5.75	NS
	K	5.64	5.83	5.89	L**
			Ca (ppm)		
	N+K	17.43	9.65	8.99	L***Q*
	N	13.69	10.94	9.18	L*
	K	6.29	8.56	8.25	NS
			K (ppm)		
	N+K	14.91	10.13	6.21	L***[w]
	N	3.70	4.57	2.78	NS
	K	13.76	10.23	7.07	L***

[z]Responses to percentage of nutrients trickle-applied were linear (L) or quadratic (Q) at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS).

[y]Interactions for K concentration were significant for the N+K vs N x trickle-applied percentage of nutrients L (**) and N vs K x trickle-applied percentage of nutrients L (**).

[x]Interactions for pH were significant for the N+K vs N x trickle-applied percentage of nutrients L (***) and N vs K x trickle-applied percentage of nutrients L (**).

[w]Interactions for K concentration were significant for N+K vs N x trickle-applied percentage of nutrients L (***) and for N vs K x trickle-applied percentage of nutrients L (***).

Table 2-32. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on soil test values 9 weeks after transplanting. Bed center 0-10 cm.

Treatment	pH	Soluble salts ($dS \cdot m^{-1}$)	Soil mineral concn (ppm)					
			NO_3-N	NH_4-N	P	K	Ca	Mg
Year (Yr)								
1984	6.18	0.83	2.04	0.30	2.00	8.52	8.87	1.42
1985	5.30	1.34	10.58	2.71	0.47	19.23	22.41	5.04
Signif.[z]	**	*	**	*	***	**	*	*
Nutrients applied (NUT)								
N+K	5.72	0.84b[y]	4.52	0.81b	1.35a	11.40	11.27b	2.49b
N	5.74	1.20a	6.72	1.21b	1.03b	13.71	20.55a	4.24a
K	5.76	1.22a	7.68	2.49a	1.33a	16.51	15.11ab	2.96b
Yr x NUT	NS	NS	NS	*	NS	*	NS	NS
Trickle-applied (%)								
50	5.79	1.14	8.58	2.31	1.08	12.03	17.15	3.86
75	5.73	1.01	4.79	1.29	1.29	13.31	14.25	2.79
100	5.70	1.11	5.55	0.92	1.33	16.28	15.53	3.03
Signif.	NS	NS	NS	L*	L*	NS	NS	NS
NUT x %	NS	NS	*	NS	NS	NS	NS	NS
Schedule								
Variable	5.72	1.07	6.26	1.38	1.20	14.35	15.63	3.16
Constant	5.77	1.10	6.35	1.63	1.27	13.40	15.66	3.29
Signif.	NS	NS	NS	NS	NS	NS	NS	NS

[z]Main effects or interactions were significant at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS). Significant responses to the percentage of nutrients trickle-applied were linear (L).
[y]Mean separation by Duncan's multiple range test, 5% level.

Table 2-33. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on soil test values 9 weeks after transplanting. Bed edge 10-20 cm.

Treatment	pH	Soluble salts ($dS\cdot m^{-1}$)	Soil mineral concn (ppm)					
			NO_3-N	NH_4-N	P	K	Ca	Mg
Year (Yr)								
1984	6.19	0.77	2.81	0.33	1.32	8.08	9.45	1.23
1985	5.28	0.89	9.69	1.33	0.16	6.68	15.48	4.46
Signif.[z]	***	NS	*	*	*	NS	**	**
Nutrients applied (NUT)								
N+K	5.73	0.78	5.59	0.72	0.73ab[y]	5.58b	12.77	3.20
N	5.77	0.91	7.75	0.92	0.83a	10.25a	12.91	2.91
K	5.71	0.80	5.41	0.85	0.65b	6.31b	11.71	2.42
Yr x NUT	NS	NS	NS	NS	*	***	**	*
Trickle-applied (%)								
50	5.80	0.77	5.35	0.84	0.72	6.72	10.71	2.33
75	5.75	0.84	8.55	0.88	0.74	8.06	13.02	2.97
100	5.66	0.88	4.84	0.76	0.76	7.39	13.66	3.22
Signif.	L**	L*	Q*	NS	NS	NS	L*	NS
Yr x %	NS	**	**	NS	NS	NS	**	NS
Schedule								
Variable	5.72	0.86	6.70	0.93	0.72	7.51	12.95	3.08
Constant	5.75	0.79	5.79	0.73	0.75	7.25	11.98	2.62
Signif.	NS	NS	NS	NS	NS	NS	NS	NS

[z]Main effects or interactions were significant at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS). Significant responses to the percentage of nutrients trickle-applied were linear (L) or quadratic (Q).
[y]Mean separation by Duncan's multiple range test, 5% level.

linear increases in soil pH and soluble salt and Ca concentrations were obtained with an increase in trickle-applied percentage of nutrients in 1985 (Table 2-34). Linear and quadratic trends in NO_3-N concentration were obtained in 1984 and 1985, respectively.

Soluble salt and K concentrations at 10-20 cm in the bed center tended to be higher with trickle-applied N+K and K than with trickle-applied N (preplant-applied K) (Table 2-35). Consistent significant effects of trickle-applied nutrients and trickle-applied percentage of nutrients on soil N concentration was not obtained in the soil solution of this portion of the bed. Trickle-applied nutrients and trickle-applied percentage of nutrients interacted in their effects on pH and Ca and K concentrations (Table 2-31).

At 13 weeks, the concentration of soluble salts in the upper portion of the edge of the bed (0-10 cm) were still higher when N and K were trickle-applied individually than with N+K (Table 2-36). Concentrations of N and K were lower when the respective nutrient was trickle-applied than when the nutrient was preplant-applied. Linear decreases in soluble salt, K, and Ca concentrations were obtained as the trickle-applied percentage of nutrients increased.

At the center of the bed (0-10 cm) (Table 2-37) higher K concentrations were obtained when K (but not when N+K) was trickle-applied than when N was injected (Table 2-38).

Table 2-34. Interaction of year and percentage of nutrients trickle-applied on soil test values 9 weeks after transplanting.

Location and depth in bed	Year	Soil test value: Trickle-applied (%) 50	75	100	Signif.[z]
		Soluble salts ($dS \cdot m^{-1}$)			
Edge 10-20 cm	1984	0.81	0.75	0.75	NS
	1985	0.72	0.94	1.02	L**
		NO_3-N (ppm)			
	1984	5.67	1.51	1.23	L*
	1985	5.02	15.59	8.46	Q**
		Ca (ppm)			
	1984	10.03	8.98	9.33	NS
	1985	11.04	17.08	17.98	L***
		Soluble salts ($dS \cdot m^{-1}$)			
Center 10-20 cm	1984	0.60	0.66	0.73	L*
	1985	0.69	0.78	1.01	NS
		Ca (ppm)			
	1984	6.44	6.65	7.25	NS
	1985	11.18	13.19	17.70	L**

[z]Significant effects were linear (L) or quadratic (Q) at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS).

Table 2-35. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on soil test values 9 weeks after transplanting. Bed center 10-20 cm.

Treatment	pH	Soluble salts ($dS \cdot m^{-1}$)	Soil mineral concn (ppm)					
			NO_3-N	NH_4-N	P	K	Ca	Mg
Year (Yr)								
1984	6.22	0.66	5.13	1.06	1.99	7.77	6.65	0.87
1985	5.30	0.86	11.34	1.13	0.23	8.61	14.02	2.93
Signif.[z]	**	*	NS	NS	***	NS	**	**
Nutrients applied (NUT)								
N+K	5.72	0.85a[y]	5.68	0.93	1.09ab	10.42a	12.03b	2.03a
N	5.78	0.67b	9.15	0.74	1.00b	3.68b	11.27a	2.24a
K	5.79	0.76ab	9.88	1.62	1.24a	10.42a	7.90b	1.43b
Yr x NUT	NS	NS	*	NS	NS	NS	**	*
Trickle-applied (%)								
50	5.83	0.64	8.79	0.76	1.01	5.35	8.81	1.83
75	5.79	0.72	6.91	1.70	1.19	8.31	9.72	1.87
100	5.67	0.92	9.01	0.82	1.13	10.86	12.47	2.00
Signif.	L***	L***	NS	NS	NS	L***	L**	NS
Yr x %	NS	*	NS	NS	NS	NS	*	NS
NUT x %	**	NS	NS	NS	NS	*	**	NS
Schedule								
Variable	5.72	0.75	9.15	1.29	1.06	8.41	10.48	1.93
Constant	5.79	0.79	7.32	0.91	1.15	7.93	10.19	1.87
Signif.	NS	NS	NS	NS	NS	NS	NS	NS

[z]Main effects or interactions were significant at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS). Significant responses to the percentage of nutrients trickle-applied were linear (L).

[y]Mean separation by Duncan's multiple range test, 5% level.

Table 2-36. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on soil test values 13 weeks after transplanting. Bed edge 0-10 cm.

Treatment	pH	Soluble salts ($dS \cdot m^{-1}$)	Soil mineral concn (ppm)					
			NO_3-N	NH_4-N	P	K	Ca	Mg
Year (Yr)								
1984	6.43	2.03	10.40	5.41	1.27	22.40	28.67	5.58
1985	5.49	1.53	7.42	2.16	0.11	11.50	31.89	8.85
Signif.[z]	***	*	NS	*	***	NS	NS	***
Nutrients applied								
N+K	5.93	1.28b[y]	4.36b	1.91b	0.87a	7.98b	22.69b	5.50b
N	6.00	2.10a	5.98b	2.73b	0.67b	34.96a	32.12a	8.04a
K	5.94	1.97a	16.49a	6.73a	0.54b	7.96b	36.01a	8.11a
Trickle-applied (%)								
50	5.95	2.07	10.11	4.62	0.63	20.48	36.28	8.11
75	5.98	1.63	7.15	3.06	0.66	16.02	27.74	6.68
100	5.94	1.66	9.57	3.69	0.80	14.39	26.80	6.88
Signif.	NS	L**	NS	NS	NS	L*	L**	NS
Schedule								
Variable	5.94	1.84	9.43	3.78	0.67	17.87	29.59	7.23
Constant	5.97	1.73	8.46	3.80	0.72	16.06	30.97	7.20
Signif.	NS	NS	NS	NS	NS	NS	NS	NS

[z]Main effects or interactions were significant at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS). Significant responses to the percentage of nutrients trickle-applied were linear (L).

[y]Mean separation by Duncan's multiple range test, 5% level.

Table 2-37. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on soil test values 13 weeks after transplanting. Bed center 0-10 cm.

Treatment	pH	Soluble salts ($dS \cdot m^{-1}$)	Soil mineral concn (ppm)					
			NO_3-N	NH_4-N	P	K	Ca	Mg
Year (Yr)								
1984	6.61	0.85	2.03	1.51	2.01	7.74	11.24	2.62
1985	5.53	0.98	3.53	1.45	0.43	13.49	19.76	3.59
Signif.[z]	***	NS	NS	NS	**	*	NS	NS
Nutrients applied (NUT)								
N+K	6.00b[y]	0.80	1.98	1.14	1.53	8.72b	13.33	2.60
N	6.04b	0.90	3.48	1.52	1.01	7.46b	16.62	3.26
K	6.17a	1.04	2.89	1.77	1.12	15.59a	16.55	3.45
Yr x NUT	NS	NS	NS	NS	NS	**	NS	NS
Trickle-applied (%)								
50	6.10	0.89	2.42	1.46	0.96	8.96	14.76	3.10
75	6.08	0.94	2.70	1.43	1.56	11.50	15.92	3.08
100	6.02	0.92	3.22	1.54	1.14	11.31	15.82	3.13
Signif.	NS	NS	NS	NS	NS	NS	NS	NS
NUT x %	NS	NS	NS	*	NS	NS	NS	NS
Schedule								
Variable	6.07	0.89	2.90	1.36	1.05	10.83	14.62	2.98
Constant	6.07	0.94	2.66	1.60	1.39	10.35	16.39	3.23
Signif.	NS	NS	NS	NS	NS	NS	NS	NS

[z]Main effects or interactions were significant at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS).

[y]Mean separation by Duncan's multiple range test, 5% level.

Table 2-38. Interaction of year and trickle-applied nutrients on soil K concentration 13 weeks after transplanting at 0-10 cm in the center of the bed.

	Soil mineral concn (ppm)		
	Nutrients applied		
Year	N+K	N	K
1984	8.45ab[z]	5.04b	9.72a
1985	8.99b	9.88b	21.46a

[z]Mean separation within years by Duncan's multiple test range, 5% level.

A linear decrease and a linear increase in NH_4-N concentration were obtained as the trickle-applied percentage of N and K increased, respectively (Table 2-39).

In the lower portion (10-20 cm) of the edge of the bed, lower NH_4-N concentrations were obtained when N+K and N were trickle-applied than when K was trickle-applied (preplant-applied N) but the NO_3-N concentration was unaffected by trickle-applied nutrients (Table 2-40). Year, trickle-applied nutrients, and percentage of nutrients trickle-applied interacted in their effects on the soil K concentration (Table 2-41).

At the center of the bed (10-20 cm), soluble salt and K concentrations were significantly higher when N+K and K were trickle-applied than when N was trickle-applied (preplant-applied K) (Table 2-42). Trickle-applied nutrients and trickle-applied percentage of nutrients interacted in their effects on pH and K, Ca, and Mg concentrations. A linear decrease in pH but linear increases in K, Ca, and Mg concentrations were obtained as the trickle-applied percentage of N+K increased from 50 to 100% (Table 2-39). Trends in these soil test values were not affected significantly by the trickle-applied percentage of N or K applied individually except for a linear increase in the K concentration when K was trickle-applied.

Table 2-39. Interaction of trickle-applied nutrients and percentage of nutrients trickle-applied on soil test values 13 weeks after transplanting.

Location and depth in bed	Nutrients applied	Soil test value: Trickle-applied (%) 50	75	100	Signif.[z]
			NH_4-N (ppm)		
Center 0-10 cm	N+K	0.91	1.33	1.19	NS[y]
	N	2.22	1.44	0.91	L*
	K	1.26	1.53	2.52	L*
			pH		
Center 10-20 cm	N+K	6.15	6.04	5.92	L***
	N	6.15	6.08	6.09	NS
	K	6.22	6.31	6.24	NS
			Ca (ppm)		
	N+K	6.04	7.66	11.99	L***
	N	7.83	8.32	9.53	NS
	K	8.41	6.71	5.64	NS
			Mg (ppm)		
	N+K	1.24	1.43	2.23	L**
	N	1.68	1.64	1.76	NS
	K	1.84	1.45	1.19	NS
			K (ppm)		
	N+K	3.44	8.17	8.82	L*[x]
	N	2.31	2.36	1.62	NS
	K	8.94	13.88	15.44	L***

[z]Responses to percentage of nutrients trickle-applied were linear (L) at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS).
[y]Interactions for NH_4-N concentration were significant for N vs K x trickle-applied percentage of nutrients L (*).
[x]Interactions for K concentration were significant for N+K vs N x trickle-applied percentage of nutrients L (***) and for N vs K x trickle-applied percentage of nutrients L (***).

Table 2-40. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on soil test values 13 weeks after transplanting. Bed edge 10-20 cm.

Treatment	pH	Soluble salts ($dS\cdot m^{-1}$)	Soil mineral concn (ppm) NO_3-N	NH_4-N	P	K	Ca	Mg
Year (Yr)								
1984	6.61	0.85	2.50	1.85	1.36	6.70	12.11	2.54
1985	5.53	0.67	2.29	2.43	0.13	3.02	13.34	3.75
Signif.[z]	***	*	NS	NS	***	***	NS	NS
Nutrients applied (NUT)								
N+K	6.01b[y]	0.73	2.03	1.29b	0.70	3.86b	11.99ab	3.26
N	6.13a	0.71	2.48	1.71b	0.87	7.38a	10.96b	2.87
K	6.07ab	0.84	2.69	3.44a	0.67	3.34b	15.22a	3.31
Trickle-applied (%)								
50	6.10	0.72	2.31	2.17	0.71	4.58	11.88	3.22
75	6.07	0.80	2.81	2.67	0.71	4.62	14.27	3.54
100	6.04	0.75	2.08	1.59	0.82	5.38	12.03	2.68
Signif.	NS	NS	NS	NS	NS	NS	NS	NS
Yr x NUT x %	NS	NS	NS	NS	NS	*	NS	NS
Schedule								
Variable	6.05	0.74	2.15	2.25	0.75	4.67	11.98	2.78
Constant	6.09	0.77	2.65	2.04	0.74	5.05	13.46	3.51
Signif.	NS	NS	NS	NS	NS	NS	NS	NS

[z]Main effects or interactions were significant at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS).

[y]Mean separation by Duncan's multiple range test, 5% level.

Table 2-41. Interaction of year, trickle-applied nutrients, and percentage of nutrients trickle-applied on soil K and NH_4-N concentrations 13 weeks after transplanting.

		Soil mineral concn (ppm)							
		1984				1985			
		Trickle-applied (%)				Trickle-applied (%)			
Location in bed	Nutrients applied	50	75	100	Signif.[z]	50	75	100	Signif.
					K				
Edge 10-20 cm	N+K	6.10	4.10	3.06	NS	3.52	2.41	3.96	NS
	N	8.90	18.88	16.13	L***	1.75	3.49	2.11	NS
	K	2.74	3.81	3.55	NS	4.45	2.04	3.45	NS
					NH_4-N				
Center 10-20 cm	N+K	1.99	2.53	0.90	L*[y]	0.86	1.18	1.21	NS
	N	3.32	0.75	1.47	NS	0.94	1.15	1.06	NS
	K	1.69	3.03	1.89	L***	1.46	0.86	0.84	L*

[z]Responses to the percentage of nutrients trickle-applied were linear (L) at the 5% (*) or 0.1% (***) level or nonsignificant (NS).

[y]The interaction for NH_4-N concentration was significant for N+K vs K x trickle-applied percentage (*).

Table 2-42. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on soil test values 13 weeks after transplanting. Bed center 10-20 cm.

		Soluble salts	Soil mineral concn (ppm)					
Treatment	pH	($dS \cdot m^{-1}$)	NO_3-N	NH_4-N	P	K	Ca	Mg
Year (Yr)								
1984	6.66	0.68	2.97	1.95	1.98	6.70	7.92	1.98
1985	5.61	0.53	2.30	1.06	0.26	8.18	7.89	1.23
Signif.[z]	***	**	NS	*	***	NS	NS	**
Nutrients applied (NUT)								
N+K	6.04c[y]	0.62a	2.13	1.45	0.97	7.48b	8.56	1.64
N	6.11b	0.54b	2.70	1.45	1.35	2.09c	8.56	1.69
K	6.26a	0.66a	3.05	1.62	1.05	12.75a	6.59	1.49
Trickle-applied (%)								
50	6.18	0.57	2.14	1.71	0.90	5.56	7.43	1.59
75	6.14	0.61	2.32	1.57	1.05	8.14	7.23	1.51
100	6.09	0.64	3.44	1.23	1.41	8.63	9.05	1.73
Signif.	L*	NS	NS	NS	NS	L**	NS	NS
NUT x %	*	NS	NS	NS	NS	*	*	*
Yr x NUT x %	NS	NS	NS	*	NS	NS	NS	NS
Schedule								
Variable	6.13	0.62	2.67	1.45	0.94	7.47	7.96	1.57
Constant	6.14	0.60	2.59	1.56	1.30	7.41	7.85	1.64
Signif.	NS	NS	NS	NS	NS	NS	NS	NS

[z]Main effects or interactions were significant at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS). Significant responses to the percentage of nutrients trickle-applied were linear (L).
[y]Mean separation by Duncan's multiple range test, 5% level.

Shoot Production

Fresh and dry plant shoot weights were significantly higher in 1985 than in 1984 but the dry weight percentages were similar in both years (Table 2-43). Trickle-applied nutrients and schedule of nutrient application interacted in their effects on shoot fresh weights (Table 2-44). Trickle-applied nutrients and year interacted in their effects on dry shoot weights (Table 2-45). In 1984, fresh and dry shoot weights decreased linearly as the trickle-applied percentage of nutrients increased (Table 2-46). In 1985, a quadratic trend was obtained.

Discussion

Fruit Yield

The major effect of trickle-applied nutrients on some important early yield size categories occurred in 1984. Yields tended to be higher when N was preplant-applied (K trickle-applied) than when N+K and N were trickle-applied. Early yields of fruit in most size categories decreased significantly as the trickle-applied percentage of nutrients increased. The importance of adequate N availability for high yields early in the season was further indicated by the interaction of trickle-applied nutrients and the percentage of nutrients trickle-applied on the early yield of medium and marketable fruit in both

Table 2-43. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, and schedule of nutrient application on shoot weight.

Treatment	Shoot weight ($g \cdot plant^{-1}$) Fresh	Dry	Dry weight (%)
Year (Yr)			
1984	887	126	0.14
1985	1560	206	0.13
Signif.[z]	***	**	NS
Nutrients applied (NUT)			
N+K	1232	166	0.14
N	1201	166	0.14
K	1237	167	0.14
Signif.	NS	NS	NS
Yr x NUT	NS	*	NS
Trickle-applied (%)			
50	1258	172	0.14
75	1172	161	0.14
100	1241	166	0.14
Signif.[z]	Q*	NS	NS
Yr x %	*	**	NS
Schedule (S)			
Variable	1251	168	0.14
Constant	1196	168	0.14
Signif.	NS	NS	NS
NUT x S	**	NS	NS

[z]Main effects or interactions were significant at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS). A response to the percentage of nutrients trickle-applied was quadratic (Q).

Table 2-44. Interaction of trickle-applied nutrients and schedule of nutrient application on fresh weight of shoots.

Nutrients applied	Shoot fresh weight ($g \cdot plant^{-1}$) Schedule: Variable	Constant
N+K	1336a[z]	1129b
N	1197b	1205ab
K	1221b	1254a

[z]Mean separation within schedules of nutrient application by Duncan's multiple range test, 5% level.

Table 2-45. Interaction of year and trickle-applied nutrients on shoot dry weight.

Nutrients applied	Shoot dry weight ($g \cdot plant^{-1}$) Year: 1984	1985
N+K	122b[z]	210
N	122b	210
K	135a	198

[z]Mean separation within years by Duncan's multiple range test, 5% level.

Table 2-46. Interaction of year and percentage of nutrients trickle-applied on fresh and dry weight of shoots.

Year	Shoot weight (g·plant^{-1}) Trickle-applied (%) 50	75	100	Signif.[z]
		Fresh		
1984	932	893	837	L*
1985	1583	1452	1645	Q**
		Dry		
1984	198	127	118	L**
1985	209	195	314	Q*

[z]The response to percentage of nutrients trickle-applied was linear (L) or quadratic (Q) at the 5% (*) or 1% (***) level.

years. Linear decreases in yield were obtained as the percentage of trickle-applied N+K and N increased. Yields of marketable fruit were similar when 50% of the N+K and N were preplant-applied (mean 25.4 $t \cdot ha^{-1}$) and when all the N was preplant-applied (trickle-applied K; mean 26.6 $t \cdot ha^{-1}$). These yields of marketable fruit were almost twice as great as the yields of marketable fruit obtained when 100% of the N+K and N were trickle-applied (mean 16.4 $t \cdot ha^{-1}$).

Evidence for the importance of adequate N early in the season for high fruit yield was also obtained at midseason. When N+K and N were trickle-applied, the yield of large fruit was higher when portions of the fertilizer were preplant-applied than when all the fertilizer was trickle-applied. The yield of small and marketable fruit was higher, but not significantly greater, when N was trickle-applied than when N was preplant-applied (trickle-applied K). The greatest yields of large and marketable fruit were obtained when 75% of the N+K and N was trickle-applied. The quadratic yield response obtained at midseason occurred in part because of the high yield obtained with 50% trickle-applied N+K and N early in the season.

By the late harvest, few significant differences in yield due to trickle-applied nutrients were obtained, although a trend towards lower yields with preplant-applied N (trickle-applied K) than with trickle-applied N+K and N

were observed. This trend was expected because yields from the latter treatments were high earlier in the season. The trend towards higher yields with an increase in the percentage of trickle-applied nutrients was expected because yields decreased with an increase in trickle-applied percentage of nutrients earlier in the season. However, significant increases in yield were obtained (at the 15% level) only in large and marketable fruit.

The greater total yield of large fruit in 1984 (35.1 $t \cdot ha^{-1}$) than in 1985 (26.1 $t \cdot ha^{-1}$) occurred because of the longer growing season (111 and 92 days in 1984 and 1985, respectively) and extended harvest period (5 and 4 weeks in 1984 and 1985, respectively) in 1984 than in 1985. The yield of small fruit obtained at the late harvest in 1984 was almost 5 times greater in 1985 than in 1984. The importance of providing adequate N to obtain high yields was indicated by the interaction of trickle-applied nutrients and trickle-applied percentage of nutrients on the total yield of large fruit. A linear decrease in mean total yield of large fruit from 33.3 $t \cdot ha^{-1}$ to 25.2 $t \cdot ha^{-1}$ was obtained when N+K and N, respectively, were trickle-applied, whereas yields (mean 31.1 $t \cdot ha^{-1}$) were not significantly affected when N was preplant-applied (trickle-applied K).

The weekly schedule of nutrient application had few significant effects on fruit yield, shoot production, leaf, plant and soil mineral nutrient concentration.

Leaf and Shoot Mineral Nutrient Concentration

At 5 weeks after planting in 1984 when N+K and N were trickle-applied the mean leaf N concentration decreased linearly from 6.09 to 5.50% with an increase in trickle-applied percentage of nutrients, but when N was preplant-applied (trickle-applied K) significant differences were not obtained (mean 6.53%). In both years trends in yield similar to these trends in leaf N concentration were obtained in many important yield categories at the early and midseason harvests as well as in the total yield of large fruit.

In 1985, leaf samples were not taken at 5 weeks. At 7 and 9 weeks, significant differences in leaf N concentration were not obtained between trickle- and preplant-applied N. By 11 and 13 weeks, leaf N concentrations obtained when N was preplant-applied (preplant-applied K) had decreased more than when N+K and N were trickle-applied, but the former treatment resulted in higher fruit yields than the latter treatments. Evidently high early season leaf N, not the accumulation of trickle-applied N late in the season, was associated with high fruit yields. Decreases in leaf N concentrations of plants supplied with trickle- (24,30,45) and preplant- (21,30,46) applied N have been reported.

At 5 weeks after planting in 1984, leaf K concentrations were similar when N+K and K were trickle-applied.

A linear decrease in the mean K concentration from 2.58 to 2.19% was obtained as the trickle-applied percentage of N+K and K increased, but when K was preplant-applied (trickle-applied N) significant differences were not obtained with an increase in trickle-applied percentage of K (mean 2.52%). At 7 weeks, the effect of trickle-applied nutrients was not consistent, but from 9 to 13 weeks the K concentration was lower with preplant-applied K (trickle-applied N) than with trickle-applied N+K and K. Higher K concentrations in shoot tissue were also obtained with trickle-applied N+K and K than with preplant-applied K (trickle-applied N). Decreases in leaf K concentrations of plants supplied with trickle- (24,30) and preplant-applied (21) K have been reported.

High fruit yield early in the season was not associated with high late season leaf K concentrations. If this were the case, yields with trickle-applied N+K would have been as high as those obtained with trickle-applied K.

Evidence for NH_4-N inhibition of K uptake (50) was not obtained.

Soil Test Analyses

When N and K were trickle-applied individually 0-50% of each nutrient and all of the other nutrient were preplant-applied. The amount of both nutrients preplant-applied at each trickle-applied percentage of individually-applied N and K was greater than the quantity of both

nutrients preplant-applied when both nutrients were trickle-applied together. The amount of preplant-applied fertilizer and the low lateral movement of water observed in the upper portion of the soil of raised beds could explain the higher concentration of salts in the soil solution in the edge of the bed at 9 weeks at 0-10 cm depth when both nutrients were trickle-applied individually (mean 3.0 $dS \cdot m^{-1}$) than when N+K was trickle-applied (1.70 $dS \cdot m^{-1}$). Low lateral movement of water in the soil of raised beds has been reported (15). Differences in soluble salt concentration due to trickle-applied nutrients in the center of the bed were similar to, but not as great as, the differences in concentration obtained at the edge of the bed. The low concentrations can be attributed to nutrient leaching at the center of the bed resulting from daily applications of irrigation water.

At the edge of the bed, water movement within the bed was probably greater at 10-20 cm than at 0-10 cm due to the presence of a high water table following heavy rainfall events. At 10-20 cm, significant differences in soluble salt concentrations due to trickle-applied nutrients were not obtained at the bed edge. Statistically significant differences obtained at both depths in the bed center were probably of little biological importance at the time samples were taken because concentrations were very low.

Tomato root growth and function are affected by moderate concentrations of soluble salts in the soil solution (19). The high salt concentration could explain why fewer tomato roots were observed growing in the soil of the upper portion of the edge of the bed than in the lower portion of the edge of the bed. It must be noted that soluble salt concentrations obtained at the center of the bed were low, in part, because soil samples were taken 1 week after the most recent weekly injection of fertilizer and just prior to the next injection.

At the bed edge (0-10 cm), N and K concentrations were higher when the respective nutrient was preplant-applied than when the respective nutrient was trickle-applied. Concentrations of NO_3-N, NH_4-N, and K decreased as the trickle-applied percentage of nutrients increased because very little of the trickle-applied nutrients reached this portion of the bed. Like the soluble salt concentrations, N and K concentrations at the bed center (0-10 cm) appeared to be lower than at the bed edge. At the bed center, concentrations of N and K were low due to continuous leaching. Significant effects of trickle-applied nutrients and the percentage of nutrients trickle-applied probably had little significant biological importance.

In both years, at 10-20 cm in both locations in the bed, significant differences in N concentration due to trickle-applied nutrients were not obtained, probably

because of NO_3-N leaching by the fluctuating water table. Potassium concentrations at the bed edge were higher when K was preplant-applied than when K was trickle-applied in 1984 only. At the bed center where nutrient leaching by irrigation water was greater, K concentrations were significantly higher with trickle-applied N+K and K than with preplant-applied K probably because of the accumulation of trickle-applied K from the upper portion of the bed.

At 13 weeks after transplanting, the soluble salt concentration at 0-10 cm in the bed edge was still considerably higher when N and K were trickle-applied individually than when they were injected. In the center of the bed, differences in soluble salt concentration due to trickle-applied nutrients were not expected nor were differences obtained. At 10-20 cm in the bed edge and at both depths in the bed center, similar nonsignificantly different concentrations were obtained. Salt concentrations at 0-10 cm but not at 10-20 cm (which were lower than 1 $dS \cdot m^{-1}$ at 9 weeks) appeared to be lower at 13 weeks than at 9 weeks.

Nitrogen concentrations in the upper portion of the bed edge, but not at the bed center, were still greater with preplant-applied N than with trickle-applied N+K and N. The K concentration in the bed edge was still greater with preplant-applied K than with trickle-applied K but at

the bed center the effect of nutrient injection was not the same in both years. The reduction in N and K concentrations between sampling times appeared to be greater at the bed edge than at the bed center because of the higher nutrient concentrations in the edge at the earlier sampling time. The progressive reduction in the concentration of preplant-applied K at the bed edge has been reported (27).

At 10-20 cm in both locations in the bed, significant interactions of year and trickle-applied nutrients on soil test values did not occur, indicating that similar effects were obtained at 13 weeks in both years. At the bed edge, the NH_4-N concentration was higher with preplant-applied N than with trickle-applied N. At 9 weeks, there were no significant differences in NH_4-N concentration due to trickle-applied nutrients. However, the values at 9 weeks (0.72-0.92 ppm) appeared to be lower than the values at 13 weeks (1.29-3.44 ppm). This indicates that fertilizer leached from the upper portion of the bed may have accumulated deeper in the bed as the level of the water table fluctuated. Significant differences in NO_3-N concentration due to trickle-applied nutrients were not obtained at either sampling period at 10-20 cm. Although the NO_3-N concentrations were reduced approximately 50% between sampling periods, the significance of the reduction was not great because the N concentration at 9 weeks was

low. Also, an apparent decrease in K concentration was observed between sampling periods, but K concentrations were still greater with preplant- than with trickle-applied K.

At 10-20 cm in the center of the bed, an apparent decrease in the NO_3-N concentration but no difference in the NH_4-N concentration was observed between sampling times. At both sampling times, great differences in N concentration due to trickle-applied nutrients were not obtained. Although K concentrations were low at both sampling times, K concentrations were still higher when N+K and K were trickle-applied than when K was preplant-applied. The relatively high soil solution K but not N concentrations obtained in the most highly leached portion of the bed a week after fertilizer injection can be explained by the greater retention of K^+ than NH_4-N as well as the nitrification of NH_4-N and subsequent leaching of NO_3-N.

CHAPTER III
EXTERIOR AND INTERIOR BLOTCHY RIPENING AND FRUIT MINERAL NUTRIENT CONCENTRATION

Literature Review

Irregular or defective ripening of tomato fruit known as blotchy ripening has been recognized as a serious problem for quite some time (5). Both external and internal pericarp may be blemished. External blotchy ripening is important to the industry because of the reluctance of consumers and wholesalers to purchase the fresh product when blemished (1). The presence of blotchy-ripened areas, especially the shoulder, reduces the price received for whole packed tomatoes due to discoloration but primarily because of great difficulty in removing the peel from affected portions of the fruit (11). This disorder has been reported in many parts of the world including Florida (19), Canada (10,33), and the United Kingdom (53). According to the New York State County Extension Service, most plantings are affected (12).

There is considerable variation in the literature with regards to the terminology of blotchy ripening. Three types of abnormal coloration of portions of red ripe pericarp are referred to as external blotchy ripening

herewithin: 1) virtually colorless through yellow-orange-green discolored areas which vary in size and shape, have well-defined margins, and are found especially near the shoulder area; 2) a less distinct discoloration in which vascular bundles are observed within the outer pericarp wall; and 3) a (near) ringing of the stem scar by a yellow band (35). Internally, the disorder is characterized by a white discoloration of the normally red ripe pericarp. The texture of blotchy-ripened areas may be uncharacteristically hard.

The role of mineral nutrition (especially K), temperature, sunlight, and genetics on the incidence of external (5,10,19,33,49) and internal (37) blotchy ripening has been reported. Increasing the K rate from 0 to 745 kg $K \cdot ha^{-1}$ resulted in a reduction but not the elimination of blotchy ripening and an increase in pericarp and leaf K concentrations in spring and fall crops but neither form of the disorder was eliminated at the highest rate (39). The dissimilar susceptibility of four cultivars to blotchy ripening was not associated with differences in the K concentration of either tissue. A decrease in the incidence of exterior blotchy ripening of trickle-irrigated tomatoes was reported as the K:N ratio increased from 0.8 to 2.1:1 (52).

The objective of these studies was to determine the effect of trickle-applied N and/or K, percentage of

trickle-applied nutrients (50-100%), schedules of nutrient application (variable, 2-12.5% weekly and constant, 8.3% weekly), and harvest period on the exterior and interior quality and the mineral nutrient concentration of 'Sunny' tomatoes.

Materials and Methods

Tomatoes were grown as described in Chapter II. Ten small size breaker-stage fruit per plot were obtained at the early, midseason, and late harvests in both years. Each fruit was selected from a different plant. To reduce the possibility of sunscalding only fruit shaded from direct sunlight were selected. Fruit were washed in a 125 ppm solution of chlorine (hypochlorite) and stored for approximately 7 days at 21°C. Red ripe fruit were evaluated for both external and internal blotchy ripening using the following scale: 1) blotch-free; 2) 0-5% blotchy; 3) 5-25% blotchy; 4) 25-50% blotchy; and 5) greater than 50% blotchy (39). Following the rating for external blotchy ripening each fruit was cut across the equatorial plane then rated for internal blotchy ripening. Entire opposite polar quarters of each fruit were pooled then pureed in a Waring blender. Homogenate subsamples were weighed, dried at 70°C, and ground to particles with a diameter of less than 1.6 mm. Prepared fruit tissue was stored in polyethylene scintillation vials

and redried for 72 hours before further use. Additional tissue preparation for nutrient analyses of leaf and shoot tissue were performed as previously described in Chapter II.

The experimental design was a split plot. Main plot treatments were a factorial of year, nutrients trickle-applied, percent of nutrients trickle-applied, and schedule of nutrient application. Harvest period was the subplot treatment.

Results

Fruit Quality

External blotchy ripening was slightly less severe in 1985 than in 1984 but internal blotchy ripening was considerably less severe in 1984 than in 1985 (Table 3-1). Overall, internal blotchy ripening appeared to be a greater defect than external blotchy ripening.

External and internal blotchy ripening were less severe when N+K was trickle-applied than when either N or K were trickle-applied individually. Blotchy ripening was less severe when N was trickle-applied than when K was trickle-applied.

The effect of the trickle-applied percentage of nutrients on external blotchy ripening was not significant but a linear decrease in interior blotchy ripening was

Table 3-1. Main effect of year, trickle-applied nutrients, percentage of nutrients trickle-applied, schedule of nutrient application, and harvest period on fruit quality and composition.

Treatment	Blotchy-ripening rating[z] External	Blotchy-ripening rating[z] Internal	Fruit mineral concn (%) N	P	K	Ca	Mg	Dry wt (%)
Year (Yr)								
1984	1.88	2.86	2.91	0.63	4.77	0.17	0.25	4.03
1985	1.66	3.39	2.99	0.44	3.55	0.14	0.21	4.45
Signif.[y]	*	**	NS	***	***	**	***	***
Nutrients applied (NUT)								
N+K	1.59c[x]	2.79c	3.00b	0.54a	4.40a	0.16b	0.23a	4.29a
N	1.76b	3.10b	3.06a	0.55a	4.11b	0.17a	0.23a	4.16b
K	1.97a	3.46a	2.79c	0.51b	3.99c	0.14c	0.21b	4.27a
Trickle-applied (%)								
50	1.82	3.24	2.86	0.53	4.14	0.14	0.22	4.28
75	1.90	3.08	2.99	0.54	4.23	0.16	0.23	4.22
100	1.74	3.03	3.00	0.53	4.13	0.17	0.22	4.13
Signif.	NS	L***	L***Q*	NS	Q*	L*	Q*	L*
Yr x NUT x %	NS	NS	NS	NS	NS	**	NS	NS
Schedule (S)								
Variable	1.75	3.08	2.99	0.53	4.18	0.16	0.23	4.25
Constant	1.77	3.16	2.92	0.53	4.15	0.16	0.22	4.23
Signif.	NS	NS	NS	NS	NS	NS	NS	NS
NUT x S	NS	NS	*	NS	NS	NS	NS	NS
Harvest period (H)								
Early	1.73b	2.99b	2.95	0.54a	4.32a	0.17a	0.23a	4.14c
Mid	1.75b	2.90b	2.94	0.55a	3.99c	0.16a	0.22b	4.21b
Late	1.84a	3.47a	2.97	0.51b	4.19b	0.15b	0.22b	4.37a
Yr x H	***	***	***	***	***	***	***	***

Table 3-1--continued.

[z]External and internal blotchy-ripening ratings were 1, blotch-free; 2, 0-5% blotchy; 3, 5-25% blotchy; 4, 25-50% blotchy; and 5, greater than 50% blotchy.
[y]Main effects or interactions were significant at the 5% (*), 1% (**), or 0.1% (***) level or nonsignificant (NS). Significant responses to percentage of nutrients trickle-applied were linear (L) or quadratic (Q).
[x]Mean separation by Duncan's multiple range test, 5% level.

obtained as the trickle-applied percentage of nutrients increased from 50 to 100%.

Time of harvest and year interacted in their effects on both interior and exterior fruit quality (Table 3-2). In 1984, exterior blotchy ripening was less severe at midseason than at the early and late harvests but in 1985 exterior blotchy ripening was less severe at the early and late harvests than at midseason. In both years interior quality was consistently better earlier in the season than at the late harvest.

Fruit Nutrient Composition

Results of fruit nutrient analysis indicated that N, P, K, Ca, and Mg concentrations were significantly higher when N+K and N were trickle-applied than when K was trickle-applied (Table 3-1). Potassium concentrations were significantly higher when N was trickle-applied than when K was trickle-applied.

Fruit N, K, and Mg concentration increased quadratically as the trickle-applied percentage of nutrients increased from 50 to 100%. The effect of year, trickle-applied nutrients, and trickle-applied percentage of nutrients interacted in their effects on fruit Ca concentration (Table 3-3). Trickle-applied nutrients and the weekly schedule of nutrient application interacted in their effects on fruit N concentration (Table 3-4).

Table 3-2. Interaction of year and harvest period on fruit quality and composition.

Treatment	Blotchy-ripening rating[z]		Fruit mineral concn (%)					Dry wt (%)
	External	Internal	N	P	K	Ca	Mg	
1984 harvest								
Early	1.95a[y]	2.82b	2.83b	0.62b	5.08a	0.19a	0.24b	3.94b
Mid	1.64b	2.58c	2.87b	0.66a	4.60b	0.17b	0.25a	4.08a
Late	2.06a	3.18a	3.04a	0.59b	4.64b	0.15c	0.25a	4.06a
1985 harvest								
Early	1.50b	3.15b	3.07a	0.46a	3.55b	0.14a	0.21a	4.34b
Mid	1.85a	3.21b	3.00a	0.43b	3.37c	0.15a	0.21a	4.33b
Late	1.61b	3.76a	2.89b	0.43b	3.74a	0.13b	0.20b	4.67a

[z]External and internal blotchy-ripening ratings were 1, blotch-free; 2, 0-5% blotchy; 3, 5-25% blotchy; 4, 25-50% blotchy; and 5, greater than 50% blotchy.
[y]Mean separation by Duncan's multiple range test, 5% level.

Table 3-3. Interaction of year, trickle-applied nutrients, and percentage of nutrients trickle-applied on fruit Ca concentration.

Nutrients applied	Fruit Ca concn (%) 1984 Trickle-applied (%) 50	75	100	Signif.[z]	1985 Trickle-applied (%) 50	75	100	Signif.
N+K	0.15	0.17	0.20	L***[y]	0.14	0.15	0.15	NS
N	0.16	0.19	0.21	L***	0.15	0.15	0.16	NS
K	0.14	0.15	0.15	L*	0.12	0.14	0.14	NS

[z]Significant effects were linear (L) at the 5% (*) or 0.1% (***) level or nonsignificant (NS).

[y]In 1984, interactions were significant for N+K vs N x trickle-applied percentage of nutrients linear and N+K vs K x trickle-applied percentage of nutrients linear (***).

Table 3-4. Interaction of trickle-applied nutrients and schedule of nutrient application on fruit N concentration.

Nutrients applied	Fruit N concn (%) Schedule	
	Variable	Constant
N+K	3.09a[z]	2.91b
N	3.11a	3.02a
K	2.81b	2.77c

[z]Mean separation within schedules by Duncan's multiple range test, 5% level.

Discussion

Although external blotchy ripening was statistically less severe in 1985 than in 1984 the difference in quality was not great. Internal blotchy ripening was considerably less severe in 1984 than in 1985 (when external quality was poor). In the studies reported here and in others (39) interior blotchy ripening appeared to be a more severe blemish than exterior blotchy ripening. That is, exterior quality was superior to interior quality.

Higher fruit exterior and interior quality and higher fruit N, P, K, Ca, and Mg concentrations were obtained with trickle-applied N+K and N than with preplant-applied N (trickle-applied K). Highest fruit quality and highest fruit K concentrations were obtained with trickle-applied N+K. The high fruit quality and high K concentration obtained when N+K was trickle-applied apparently resulted. The availability of both trickle-applied nutrients late in the season were important for high fruit quality because the nutrient concentrations obtained were higher when N+K was injected than when N or K were injected individually. Results of previous work showed a reduction in the incidence of blotchy ripening and an increase in fruit (39) or leaf (37,39,52) K concentration with an increase in K rate. In the studies reported here, trickle-applied NH_4-N did not inhibit K accumulation.

Interior and exterior blotchy ripening were not affected by the percentage of trickle-applied nutrients in

the same way. Exterior quality was not significantly affected. Highest interior quality and highest fruit K concentrations were obtained with 50 and 75% trickle-applied nutrients, respectively. A significant interaction between trickle-applied nutrients and trickle-applied percentage did not occur for either quality characteristic or nutrient concentration.

Year and harvest period interacted in their effects on fruit quality and fruit nutrient concentration. A consistent pattern in exterior quality was not obtained but interior quality was higher earlier in the season than at the late harvest in both years. This information may be useful to commercial tomato growers who may only harvest fruit early in the season when prices are highest. Patterns of fruit nutrient accumulation at the various harvests were not associated with fruit quality. In both years the fruit Ca concentration was higher earlier in the season than later in the season. A consistent pattern in the concentration of other nutrients was not obtained. Results of previous work with tomatoes grown on mulched beds with drip irrigation indicated that the recovery of trickle-applied ^{15}N-depleted by fruit decreased from 73 to 49% with successive harvest periods (15).

Although significant differences in the fruit dry weight percentage were obtained, the relationship between this characteristic and fruit quality or fruit nutrient

concentration was not evident. The dry matter content of blotchy ripened fruit has been reported to be low (53).

Fruit quality was not significantly affected by the weekly schedule of fertilizer application. Because there were no significant differences between the constant and variable application schedules and a rather small effect of the percentage of trickle-applied nutrients, it appears that high quality fruit can be obtained as long as small portion of the total N and K is supplied to the plant late in the season.

CHAPTER IV
SUMMARY

High yields of fruit in various size categories at the early, midseason, and total season harvest periods were obtained with high levels of preplant-applied N. At the early harvest, the yield of marketable fruit was higher with preplant-applied N (trickle-applied K) than with trickle-applied N+K and N. The early yield of marketable fruit decreased with an increase in the trickle-applied percentage of nutrients. The most important effect of N application on fruit yield was indicated by the interaction of trickle-applied nutrients and the percentage of nutrients trickle-applied. When N+K and N were trickle-applied, similar linear decreases in yield (from approximately 25.4 to 16.4 t·ha) were obtained as the percentage of trickle-applied nutrients increased. The yield was not significantly affected by the percentage of trickle-applied K (preplant-applied N, mean yield 26.6 $t \cdot ha^{-1}$). The mean yield obtained when 50% of the N and N+K was trickle-applied (25.4 $t \cdot ha^{-1}$) was similar to yield obtained with preplant-applied N. A similar pattern in the total yield of large fruit was also obtained with the

interaction of trickle-applied nutrients and the percentage of trickle-applied nutrients.

At 5 weeks after transplanting in 1984, trickle-applied nutrients and trickle-applied percentage of nutrients interacted in their effects on leaf N concentration. The mean leaf N concentration decreased linearly from 6.09 to 5.50% with an increase in the percentage of trickle-applied nutrients. When N was preplant-applied (trickle-applied K), significant differences were not obtained due to the percentage of trickle-applied nutrients (mean 6.53%). Evidently, treatments which resulted in high leaf N accumulation early in the season also resulted in high yields of fruit.

At 5 weeks, higher leaf N and K concentrations were obtained with preplant-applied N and K than with trickle-applied N and K. The concentrations of both nutrients appeared to decrease between 5 and 13 weeks. Similar decreases in N and K concentrations have been reported (21,24,30,45,46). In the studies reported here, the rate of the decrease of each nutrient was lower when the respective nutrient was trickle-applied than when the nutrient was preplant-applied. This pattern in leaf N and K concentration indicates that trickle-applied N and K were accumulated by the plants even though soil analyses indicated that soil solution N and K concentrations were very low just prior to weekly injections.

Although internal blotchy ripening appeared to be more severe than external blotchy ripening, the severity of both defects was affected similarly by trickle-applied nutrients. In addition to high late season leaf N and K concentrations, highest fruit quality and highest fruit K concentration were obtained with trickle-applied N+K. However, this treatment resulted in the lowest mean yield of fruit at the early harvest period. In previous work with preplant- (5,37,49) and trickle-applied (52) N+K and K, high incidences of blotchy ripening were related, in part, to inadequate K nutrition. In the studies reported here, poorest fruit quality, lowest fruit K concentration, and lowest late season leaf N concentration but high late season leaf K concentration were obtained with trickle-applied K (preplant-applied N).

A significant linear decrease in the severity of internal blotchy ripening was obtained as the trickle-applied percentage of nutrients increased. Because the interaction of trickle-applied nutrients and percentage of trickle-applied nutrients was not significant, it was concluded that similar high internal quality was obtained with 100% of all of the 3 trickle-applied nutrient treatments. However, the difference in interior quality obtained with 50 and 100% trickle-applied nutrients was not very great, a significant response in external quality was not observed, and very significant decreases in yield were

obtained with an increase in trickle-applied nutrients, especially N. The treatment which resulted in the greatest yield of high quality fruit was 50% trickle-applied N+K. The present recommendation is 60% trickle-applied N+K (25) based upon fruit yield only (30).

Data from plots receiving all preplant-applied N, K, and other nutrients were not analyzed statistically because of a severe bacterial wilt (Pseudomonas solanacearum) infestation and loss of plants in 1985. Adjusted mean yields obtained with this treatment at each harvest period were comparable to the mean yields obtained when nutrients were trickle-applied (Appendix). However, the overall quality and fruit N and K concentrations appeared to be lower than with trickle-applied nutrients. In a previous study (30) higher yields were obtained with 60% trickle-applied N+K than with preplant-applied fertilizer.

The weekly schedule of trickle-applied nutrients had little significant effect on the fruit yield, quality, or other parameters.

Tomato roots proliferated in the upper portion of the soil near the center of the bed near the emitters. The low soluble salt, N, and K concentrations in soil solution of samples obtained 1 week after a weekly fertilizer injection is an additional indication that N and K should be applied with the water of a trickle irrigation system.

In the studies reported here, the N and K concentrations in the above-ground plant tissue were fruit N, 93 kg; fruit K, 129 kg; shoot N, 44 kg; and shoot K, 39 kg. If fertilizer was the only source of these nutrients, the percentage of fertilizer N and K recovered would be 61 and 75%, respectively.

APPENDIX
FRUIT YIELD, QUALITY, AND COMPOSITION OBTAINED WITH PREPLANT-APPLIED FERTILIZER

Harvest period		Fruit yield category ($t \cdot ha^{-1}$)[z]					Blotchy-ripening rating[y]		Fruit concn (%)	
		Large[z]	Medium	Small	Marketable	Culls	External	Internal	N	K
1984	Early	16.6	10.7	2.8	30.1	1.3	1.85	3.10	2.55	4.90
	Mid	13.2	6.3	4.1	23.6	0.4	1.87	2.70	2.58	4.38
	Late	4.2	3.0	5.0	12.2	0	2.23	3.53	2.80	4.55
	Total	34.0	20.0	11.9	65.9	1.7	1.98	3.11	2.64	4.61
1985	Early	10.2	4.1	1.9	16.2	1.2	1.80	3.98	2.88	3.45
	Mid	8.2	6.8	6.0	21.0	0.8	2.70	3.83	2.73	3.50
	Late	7.1	11.3	22.4	40.8	1.0	1.80	4.30	2.84	3.68
	Total	25.5	22.2	30.3	78.0	3.0	2.10	4.04	2.82	3.54
Mean	Early	13.4	7.4	2.4	23.2	1.3	1.83	3.54	2.72	4.18
	Mid	10.7	6.6	5.1	22.3	0.6	2.29	3.27	2.66	3.94
	Late	5.7	7.2	13.7	26.5	0.5	2.02	3.92	2.82	4.12
	Total	29.8	21.1	21.1	72.0	2.4	2.04	3.58	2.73	4.08

[z]Mean fruit weights were large, 205 g; medium, 150 g; and small, <115 g.

[y]External and internal blotchy-ripening ratings were 1, blotch-free; 2, 0-5% blotchy; 3, 5-25% blotchy; 4, 25-50% blotchy; and 5, greater than 50% blotchy.

LITERATURE CITED

1. Agricultural Marketing Service. 1973. United States standards for grades of fresh tomatoes. USDA, Washington, D.C.

2. Bar-Yosef, B. 1977. Trickle irrigation and fertilization of tomatoes in sand dunes: Water, N, and P distributions in the soil and uptake by plants. Agron. J. 69:486-491.

3. Bar-Yosef, B., and B. Sagiv. 1982. Response of tomatoes to N and water applied via a trickle irrigation system. I. Nitrogen. Agron. J. 74:633-639.

4. Bar-Yosef, B., C. Stammers, and B. Sagiv. 1980. Growth of trickle-irrigated tomato as related to rooting volume and uptake. Agron. J. 72:815-822.

5. Beweley, W.F., and H.L. White. 1926. Some nutritional disorders of the tomato. Ann. Applied Biol. 13:323-338.

6. Bradstreet, R.B. 1965. The Kjeldhal method for organic nitrogen. Academic Press, New York, N.Y.

7. Branson, R.L., H. Schulbach, R.S. Rauschkolb, and J.M. Rible. 1981. Application of chemicals through drip systems, p. 14-19. In: E. Fereres (ed.). Drip irrigation management. Univ. of Calif. Coop. Ext. Ser. Leaflet 21259. Div. Agric. Sci., Univ. of Calif. Berkeley, Calif.

8. Bryan, H.H., W.M. Stall, J.D. Dalton, and H.W. Ford. 1975. Response of vegetables to drip and overhead irrigation on calcareous soils. Proc. Fla. State Hort. Soc. 88:190-196.

9. Carlisle, V.W., C.T. Hallmark, F. Sodek, III, R.E. Caldwell, L.C. Hammond, and V.E. Berkheiser. 1981. Characterization data for selected Florida soils. IFAS. Univ. of Fla., Gainesville, Fla.

10. Collin, G.H., and R.A. Cline. 1966. The interaction of potassium and environment on tomato ripening disorders. Can. J. Plant Sci. 46:379-387.

11. Corey, K.A, D.V. Schlimme, and B.C. Frey. 1986. Peel removal by high pressure steam from processing tomatoes with yellow shoulder disorder. J. Food Sci. 5(2):388-394.

12. Cornell Cooperative Extension. 1986. Cornell recommendations for commercial vegetable production. Cornell Univ., Ithica, N.Y.

13. Elmstron, G.W., S.J. Locascio, and J.M. Myers. 1981. Watermelon response to drip and sprinkler irrigation. Proc. Fla. State Hort. Soc. 94:161-163.

14. Feigin, A., J. Letey, and W.M. Jarrell. 1982. Celery response to type, amount, and method of N-fertilizer application under drip irrigation. Agron. J. 74:971-977.

15. Fiskell, J.G.A., and S.J. Locascio. 1983. Changes in available N for drip-irrigated tomatoes from preplant and fertigation N sources. Soil Crop Sci. Soc. Fla. Proc. 42:180-184.

16. Florida Crop and Livestock Reporting Service. 1986. Florida agricultural statistics. Vegetable summary 1985. Fla. Dept. of Agr. and Consumer Serv., Tallahassee, Fl.

17. Gallaher, R.N., C.O. Weldon, and J.G. Futral. 1975. An aluminum block digester for plant and soil analysis. Soil Sci. Soc. Amer. Proc. 39:803-806.

18. Georgia Agricultural Experiment Station. 1983. Reference soil test methods for the southern region of the United States. Southern Cooperative Series Bulletin 289. Univ. of Ga., Athens, Ga.

19. Geraldson, C.M. 1960. Nutritional factors affecting the incidence and severity of blotchy ripening of tomatoes. Proc. Fla. State Hort. Soc. 73:111-113.

20. Goldberg, D., B. Gornat, and Y. Bar. 1971. The distributi of roots, water and minerals as a result of trickle irrigation. J. Amer. Soc. Hort. Sci. 96:645-648.

21. Halbrooks, M.C., and G.E. Wilcox. 1980. Tomato plant development and elemental accumulation. J. Amer. Soc. Hort. Sci. 105:826-828.

22. Harrison, D.S. 1983. Evapotranspiration (ET) and net irrigation requirements (NIR) for crops in south and central Florida. Ag. Eng. Ext. Mimeo Report 83-10. Fla. Coop. Ext. Service, IFAS, Univ. of Fla., Gainesville, Fla.

23. Jackson, M.L. 1958. Soil chemical analysis. Prentice-Hall, Englewood Cliffs, N.J.

24. Kafkafi, U., and B. Bar-Yosef. 1980. Trickle irrigation and fertilization of tomatoes in highly calcareous soils. Agron. J. 72:893-897.

25. Kovach, S.P. 1984. Injection of fertilizer into drip irrigation systems for vegetables. IFAS, Univ. of Fla., Gainesville, Fla.

26. Lingle, J.C., and O.A. Lorenz. 1969. Potassium nutrition of tomatoes. J. Amer. Soc. Hort. Sci. 94:679-683.

27. Locascio, S.J., and F.G. Martin. 1985. Nitrogen source and application timing for trickle irrigated strawberries. J. Amer. Soc. Hort. Sci. 110(6):820-823.

28. Locascio, S.J., and J.M. Myers. 1974. Tomato response to plug mix, mulch and irrigation method. Proc. Fl. State Hort. Soc. 87:126-130.

29. Locascio, S.J., and J.M. Myers. 1979. Water and nutrient application by trickle irrigation for vegetables. Vegetable Crops Dept. Report 27-1979. IFAS, Univ. of Fla., Gainesville, Fla.

30. Locascio, S.J., J.M. Myers, and J.G.A. Fiskell. 1982. Nitrogen application, timing, and source for drip irrigated tomatoes, p. 323-328. In: A. Scaife (ed.). Proc. Ninth Intl. Plant Nutrition Colloq. Warwick Univ., England.

31. Locascio, S.J., J.M. Myers, and F.G. Martin. 1977. Frequency and rate of fertilization with trickle irrigation for strawberries. J. Amer. Soc. Hort. Sci. 102(4):456-458.

32. Marlowe, G.A., Jr., and J. Montelaro. 1978. Tomato production guide. Fl. Coop. Ext. Ser. Circ. 103D. IFAS, Univ. of Florida, Gainesville, Fla.

33. Matsumoto, T., and C.A. Hornsby. 1974. Influence of weekly changes in temperature and light regimes on the incidence of blotchy ripening of tomatoes. Can. J. Plant Sci. 54:129-133.

34. Miller, R.J., D.E. Rolston, R.S. Rauschkolb, and D.W. Wolfe. 1981. Labeled nitrogen uptake by drip-irrigated tomatoes. Agron. J. 73:265-270.

35. Minges, P.A., and S. Sadik. 1964. Blotchy ripening symptoms of tomato and procedures for rating. Proc. Fla. State Hort. Soc. 77:246-247.

36. Mitchell, C.C., Jr., and D.H. Rhue. 1979. Procedures used by the University of Florida soil testing analytical research laboratories. Soil Science Res. Rep. 791. Univ. of Fla., Gainesville, Fla.

37. Ozbun, J.L., C.L. Boutonett, S. Sadik, and P.A. Minges. 1967. Tomato fruit ripening. I. Effect of potassium nutrition on occurrence of white tissue. Proc. Amer. Soc. Hort. Sci. 91:566-571.

38. Persaud, N., S.J. Locascio, and C.M. Geraldson. 1976. Influence of fertilizer rate and placement and irrigation method on plant nutrient status, soil soluble salt and root distribution of mulched tomatoes. Soil Crop Sci. Soc. Fla. Proc. 36:121-125.

39. Picha, D.H. 1980. Effect of potassium, cultivar and season on tomato blotchy ripening, graywall, and fruit quality. Ph.D. Dissertation, Univ. of Fla., Gainesville, Fla.

40. Randall, H. 1983. Growth of cucumber (Cucumis sativus L.) and tomato (Lycopersicon esculentum) as influenced by trickle irrigation. M.S. Thesis, Univ. of Fla., Gainesville, Fla.

41. Rosen, C.J., and R.M. Carlson. 1984. Characterization of K^+ and NH_4^+ absorption by Myrobalan plum and tomato: Influence of plant potassium status and so tion concentrations of K^+ and NH_4^+. J. Amer. Soc. Hort. Sci. 109(4):522-559.

42. Rumler, E. 1986. Liquid fertilizer for Florida citrus. Citrus and Vegetable Magazine. December:10,41-43.

43. Singh, S.D., J.P. Gupta, and P. Singh. 1978. Water economy and saline water use by drip irrigation. Agron. J. 70:948-951.

44. Singh, S.D., and P. Singh. 1978. Value of drip irrigation compared with conventional irrigation for vegetable production in a hot arid climate. Agron J. 70:945-947.

45. Stark, J.C., W.M. Jarrell, J. Letey, and N. Valoras. 1983. Nitrogen use efficiency of trickle-irrigated tomatoes receiving continuous injection of N. Agron. J. 75:672-676.

46. Tanaka, A., K. Fujita, and K. Kikuchi. 1974. Nutrio-physiological studies on the tomato plant I. Outline of growth and nutrient absorption. Soil Sci. Plant Nutr. 20:57-68.

47. Tucker, D.P.H. 1978. Citrus irrigation management. Fla. Coop. Ext. Ser. Circ. 444. IFAS, Univ. of Fla., Gainesville, Fla.

48. West, D.W., I.F. Merrigan, J.A. Taylor, and G.M. Collins. 1979. Salinity gradients and growth of tomato plants under drip irrigation. Soil Sci. 127(5):281-291.

49. White, H.L. 1938. Further observations of the incidence of blotchy ripening of tomato. Ann. Appl. Biol. 25:544-557.

50. Widders, I.E., and O.A. Lorenz. 1979. Tomato root development as related to potassium nutrition. J. Amer. Soc. Hort. Sci. 104(2):216-220.

51. Widders, I.E., and O.A. Lorenz. 1982. Potassium nutrition during tomato plant development. J. Amer. Soc. Hort. Sci. 107:960-964.

52. Winsor, G.W., J.N. Davies, and M.I.E. Long. 1961. Liquid feeding of glasshouse tomatoes; The effects of potassium concentration on fruit quality and yield. J. Hort. Sci. 36:254-267.

53. Winsor, G.W., and D.M. Massey. 1958. The composition of tomato fruit. I.--The expressed sap of normal and 'blotchy' tomatoes. J. Sci. Food Agric. 9:493-498.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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